MONTHLY NOTICES

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ROYAL ASTRONOMICAL SOCIETY.

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Sydney Charles Tanner, 58 Fleming Road, Kennington Park, London, S.E. 17; and
Ernest W. Verral, 2709 Mount Tolmie Road, Victoria, B.C.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Arthur Burnet, Artificer, at the University Observatory, Oxford (proposed by H. H. Turner);

George Byfield, A.L.A.A., 32 Lushington Road, Willesden, London, N.W. 10 (proposed by B. G. Harrison);

Austin Wilfred Dobson, Nautical Instructor, 52 Elwick Road, West Hartlepool (proposed by P. J. Melotte); and

Thomas Humphries, formerly Surveyor-General of New Zealand, Stevens Road, Lower Hutt, New Zealand (proposed by C. E. Adams).

Seventy-six presents were announced as having been received since the last Meeting, including, amongst others :—

Berliner Astronomisches Jahrbuch, 1917, 1918, 1919, presented by the Astronomer Royal; and

Galileo, Dialogo, Florence, 1710, and Padua, 1744.

La Caille, Lectiones elementares Mechanicæ, 1759.

La Caille, Lectiones elementares Mathematicæ, 1772.

Mattioli, Meteore celesti, Parma, 1706.

Bion, L'usage des globes, Paris, 1710.

Scolastico, Dialogo, Padua, 1745; and

Capt. Jacob Rowe, Navigation improved, London, 1725, presented by Col. Grove-Hills; and

Photographs of Nebulæ, etc. presented by the Mount Wilson Observatory.

The Angular Diameter of α Orionis. By Professor G. E. Hale.

[*Extract from a letter to Professor Eddington.*]

December 20, 1920.

I am sure you will be interested to hear that on the night of December 13 Pease and Anderson made a first approximate measure of the diameter of α Orionis with the 20-foot Michelson interferometer attached to the 100-inch telescope. This instrument, which we built last summer, is mounted at the upper end of the tube. Two mirrors, which can be moved along carefully planed ways on the supporting steel girder, receive the light from the star and reflect it to a second pair of mirrors, mounted just above and to the right and left of the Cassegrain mirror. These send it to the 100-inch mirror, after which it follows the usual path. The observations are made at the 134-foot Cassegrain focus, with powers ranging from 1500 to 3000. Two openings in the steel girder also admit light from the star to the 100-inch mirror, to produce "zero fringes" for comparison purposes.

In the case of most stars the receiving mirrors can be placed the full length of the girder apart without decreasing the visibility of the fringes, which are extremely sharp and distinct, even on a night of seeing 2 on a scale of 10. With α Orionis the fringes were clearly visible when these mirrors were 6 feet apart. At 8 feet separation the visibility was decidedly lower, and at 10 feet the fringes had disappeared. Merrill had previously observed the decreased visibility at 8 feet for several position-angles, showing that the effect is not due to duplicity of α Orionis. At 10 feet, to make certain that the adjustments were perfect, the telescope was turned to Procyon and γ Orionis, both of which showed perfectly sharp fringes, whereas α Orionis showed none. The reappearance of the fringes at greater distances was not looked for, but it will be observed as soon as the apparatus for moving and adjusting the receiving mirrors can be improved. At present it takes Pease from half an hour to an hour to find the fringes after the mirrors have been moved. The final adjustment is made by means of optical compensating apparatus at the eye-end.

We have not yet determined the mean wave-length of the light of α Orionis, but a special quartz device is now being made for this purpose. Assuming zero visibility to occur when the receiving mirrors are 10 feet apart, and a mean wave-length of $\lambda 5500$, the angular diameter comes out $0''{\cdot}045$. This is not corrected, of course, for any effect of decreased intensity toward the limb of the star. Using the mean of three parallax determinations, two trigonometric and one by Adams, we obtain a first rough value of 540,000,000 km. for the linear diameter. This, of course, is very uncertain. But the angular diameter, which is in such close agreement with your theoretical value, is probably correct within about 10 per cent.

Pease will repeat these measures and attack other stars as soon as the interferometer has been perfected. During the past week, in spite of much cloudy weather, he observed α Ceti, α Tauri, and β Geminorum with the mirrors set at 13 feet apart. All of these stars showed definite decrease of visibility when compared with Procyon, which showed none at the same separation of the mirrors.

Hind's New Star of 1848 (*Nova Ophiuchi No.* 2).

By E. E. Barnard. (Plate 6.)

No one will question the fact that there must be hundreds of thousands of old novæ in the sky to-day which will be within the reach of modern instruments. Indeed, I believe I have accidentally come across some of these in my visual observations. It is unfortunate that we cannot identify with certainty the older novæ which were observed before the era of accurate observation, such as those of 1572 and 1670 (though Hind believed he had

located the latter star*), and others that appeared even earlier, so that they might be observed with our present means of research. Such observations would undoubtedly be of value in understanding something of their original condition. Of course there is also P Cygni, which lays some claim to having been a nova in 1600.

With the exception of P Cygni, and possibly the star of 1670, the oldest of the novæ that we can identify with certainty seems to be the one discovered by Hind in 1848. All the evidence shows that it was a true nova. Accurate observations of its position were made when it was bright, so that there is no question as to its identity to-day. It must have returned to its original condition more than half a century ago, if it at all followed the general custom of these stars. I have taken this star up in my observations of the novæ, and have identified it with certainty. On account of the considerable lapse of time since its outburst (more than 72 years), it will be more nearly in its original condition than any other nova that we can observe. I have not seen any observations of it since the ones mentioned, though there doubtless are such observations.

The star was found by Hind at Mr. Bishop's observatory, in London, on 1848 April 27, in the constellation of Ophiuchus, and was of the 4th or 5th magnitude. He described it as being remarkably vivid in the telescope. To the naked eye it was equal to ν Serpentis. Hind was confident that no star was present at this place on April 5.

The star was observed by Bond in America (*M.N.*, 9, 18, 1848), who described it as "a brilliant red, not surpassed in intensity by any other star. With power 1500 there is no indication of a planetary disc. It was of the 6th magnitude on May 25th, and at our last observation had diminished to the 7·8th . . . and with one of these, [stars] of 15th magnitude, numerous observations of position and distance have been made at different times. The mean result is

1848·52 Position 212° 8′ Distance 116″·1."

This small star (*C*) was called 15th magnitude by Bond. The proximity of the brighter nova doubtless caused the smaller star to appear much fainter than it really was, for it is now about 12·5 magnitude.

In *A.N.*, 27, 191, Hind described the nova as being reddish in the telescope, and on p. 366 he also says, "The new star of Ophiuchus was of magnitude 7 on Aug. 22 [1848] and still orange-coloured. I did not consider it brighter than magnitude 8 at the end of July." From Hind's description of the colour of the star it is probable that it was some time beyond maximum when he found it. It may, therefore, have been considerably brighter than the 4th or 5th magnitude at its greatest brightness.

* See *A.N.*, 199, 1, for a recent investigation of this star.

for the reddish colour seems to develop in these stars only when their light has diminished somewhat. During its brighter stages the star was observed at Bonn. It is B.D. $-12^{\circ}4633$. Following is a partial list of references to observations of the colour, brightness, and position of the nova: *A.N.*, 27, 191, 210, 237, and 366, 1848; *M.N.*, 8, 146, 155, and 9, 18. It was suspected by Hind and Graham to have a planetary disc, but this seems to have been disproved by Bond. But Bond's observations were later than Hind's, and from this fact may have no meaning. We find that these bodies do sometimes have a planetary disc.

I have recently examined this nova and identified it with certainty, both from its position and from Bond's comparisons with the small star nearly 2′ south of it. In these observations the nova has not seemed to be as well defined as Bond's comparison star, and the focus is probably a little outside of the normal. It is white, as is also the comparison star. I have remeasured the nova with Bond's star as well as with several other stars in the field. Their positions are shown in the accompanying diagram.

Position of the Nova.

The nova was indirectly compared with Cambridge (U.S.), *A.G.C.*, 5822, several step stars being used.

1919 June 5	$\Delta\alpha - 21^{s}\cdot88$	$\Delta\delta + 7'\ 6''\cdot5$
7	$-21^{s}\cdot92$	$+7'\ 6''\cdot0$

from which the following position results:

1919·0 $\quad \alpha\ 16^{h}\ 54^{m}\ 57^{s}\cdot70 \quad \delta - 12^{\circ}\ 46'\ 12''\cdot0.$

Following are the measures of the comparison stars. Bond's "15th magnitude star" is identified as *C* on the present diagram.

Measures of the Comparison Stars.

Nova and *C*.

1919·331	May	1	212°·07	114″·94
·344		6	211·99	115·08
·350		8	211·61	115·12
1919·342			211·89	115·05

Nova and *D*.

1919·350	May	8	190°·27	177″·46
·432	June	7	190·54	177·54
1919·391			190·40	177·50

Measures of the Comparison Stars—continued.

Nova and *E*.

1919·350	May 8	246°·80	219″·81
·402	27	246·90	219·61
·459	June 17	246·91	219·96
1919·403		246·87	219·79

Nova and *F*.

1919·355	May 10	333°·93	96″·02
·388	22	334·30	95·60
·427	June 5	333·98	95·72
1919·390		334·07	95·78

Nova and *G*.

1919·470	June 21	343°·81	49″·03
·555	July 22	344·72	49·08
1919·512		344·26	49·05

Nova and *H*.

1919·555	July 22	55°·18	35″·51

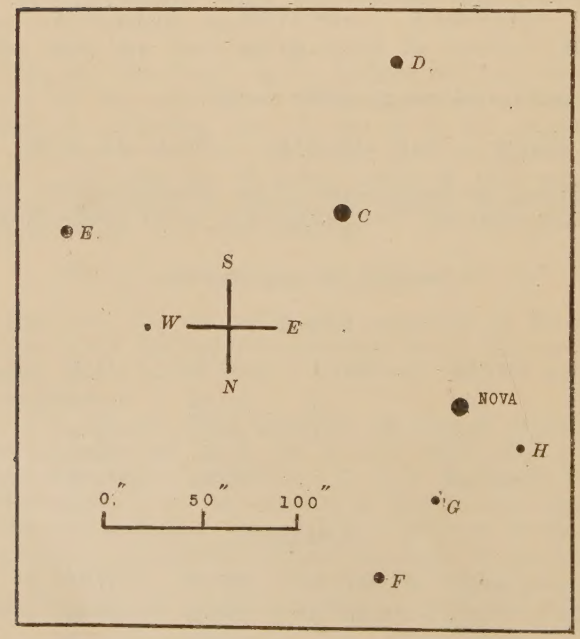

Chart of Small Stars near Hind's Nova of 1848.

Notes on the Appearance of the Nova.

The following descriptions, etc., are from the notes made at the time of the observations. From the considerable south declination of the nova the conditions have seldom been good for observation of it. The notes do not contain much information of value, but I will select a few of them which refer to its focus and physical appearance.

1919 May 1. Nova and *C* and *D* are white.

May 6. Compared with *C* it appears decidedly closely hazy. The focus seems further out than for *C*, but uncertain from bad seeing.

June 5. There is no question but that it is brighter than *C*.

June 19. The focus is perhaps slightly greater than for *C*. Measures make the focus 0·6 mm. greater. It seems to be as well defined as *C*.

June 21. It is closely hazy, while *C* is quite clear cut. The focus seems slightly greater than for *C*—say nearly 0·1 inch. It is white.

July 15. More hazy than *C* and ill defined.

July 22. Focus perhaps 0·1 inch greater than for *C*.

1920 July 3. Perhaps brighter to night.

Magnitudes of the Comparison Stars.

The following magnitudes of the comparison stars were derived from direct estimation and then by adjustment through the derived magnitudes of the nova for each night of observation, by the method described in the paper on Nova Persei in *Monthly Notices* for June 1920, **80**, 710.

$$C = 12^{m}\cdot3$$
$$D = 12\cdot9$$
$$E = 13\cdot1$$
$$F = 13\cdot4$$

I am unable to give the scale of these magnitudes. It is the regular scale adopted by me, and will be about 0·8 magnitude brighter than that of Seares of Mount Wilson (see *M.N.*, **80**, 710).

Magnitudes of the Nova.

Through comparisons with these adjusted magnitudes the brightness of the nova has been determined.

[Table

Date.	C.S.T.* h m	J.D.	Mag.	Cps.
1919 May 1	13 0	2422080	12·5	3
6	13 25	2085	12·5	2
8	13 0	2087	12·3	3
22	12 30	2101	12·4	4
27	12 20	2106	12·3	2
June 5	12 15	2115	12·1	1
7	11 0	2117	12·1	1
17	10 25	2127	12·3	1
19	10 35	2129	12·3	1
21	10 40	2131	12·3	2
28	10 40	2138	12·5	2
July 1	9 45	2141	12·3	1
5	10 40	2145	12·3	1
15	9 45	2155	12·2	1
22	8 40	2162	12·4	1
Aug. 5	8 10	2176	12·1	1
1920 May 13	12 50	2458	12·5	3
15	13 0	2460	12·5	3
20	12 50	2465	12·6	3
25	12 0	2470	12·5	3
27	12 0	2472	12·4	3
June 5	12 15	2481	12·1	3
12	11 30	2488	12·5	3
17	12 15	2493	12·4	3
July 3	10 10	2509	12·0	3
18	9 25	2524	12·5	4
Aug. 10	8 15	2547	12·7	3
14	8 55	2551	12·3	3

The magnitudes are mainly dependent on that of star *C*, but *D*, *E*, and even *F* have frequently been used. It is rather difficult to estimate the relative brightness of the nova, because its image does not seem so well defined as that of an ordinary star. The observations seem to show that it is probably variable, though the fluctuations are not large. If we take the comparisons with star *C* (which is of closely the same brightness as the nova), there seems to be good evidence that the star fluctuates through something like half a magnitude—if the light of *C* is steady. When these magnitudes are plotted there is a suggestion of a period of thirty or forty days; but the material does not seem sufficient to establish a definite period.

Direct estimates of the brightness of the nova were also made as below.

Date.	C.S.T. d h m	J.D.	Mag.
1919 May 1	13 0	2422080	12·2
8	13 0	2087	12·5
June 5	12 15	2115	12·2
1920 June 12	11 30	2488	12·2

* Central Standard Time, six hours slow of Greenwich Mean Time.

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Photograph of the Region of Hind's Nova of 1848.
1919 May 8^{d} 20^{m} 52^{s} G.M.T.
10 Bruce Telescope, Yerkes Observatory.
Exposure 0^{h} 49^{m}.

It is much brighter photographically than visually—like all the novæ, really, when at or near the end of their decline. This is strikingly shown on the accompanying photograph, where the nova appears much brighter than star *C*. This is also shown on the Wolf-Palisa Chart No. 175 (1905 May 10, exposure $2^h\ 16^m$), where it is very much brighter than *C*. The relatively greater brightness of the nova on these plates is mostly a photographic effect, but on my own photographs the relative brightness is less than on Wolf-Palisa Chart 175, showing that the star was really less bright on 1919 May 8 than on 1905 May 10. On Wolf's photograph, however, the star is outside the field of best definition, which makes the comparisons somewhat uncertain. The photographs show that *D* is red (it is only just discernible on the photograph, and will not show in the reproduction), while *E*, a fainter star visually, shows clearly.

The only reference to Hind's nova that I have found since the observations of 1848 is that in *Ann. H.C.O.*, **55**, 49: "The magnitude had decreased to 8 by June 1849. Fluctuations of a magnitude or more were found by Hind when the star had become fainter. It is believed that the magnitude has been constant at about 12·5 since 1867."

Yerkes Observatory,
Williams Bay, Wisconsin,
1920 *November* 26.

Further Observations of the Spectrum of Nova Cygni III., 1920. By Major W. J. S. Lockyer, M.A., Ph.D., and D. L. Edwards, D.I.C., A.R.C.S. (Plate 7.)

General Remarks.

Since the date of our last communication to the Society on the spectrum of this nova, further photographs have been secured. The same instrument was employed, namely, the McClean 12-inch prismatic camera, having a 12-inch prism of 20° angle. The following table gives details of the exposures:—

Date.	Number of Neg.	G.M.T. Times of Exposure. Beginning.	End.	Length of Exposure.	Mag. of Nova.
		h m	h m	h m	
1920 Nov. 2	1178	7 40	12 0	4 20	9·25
5	1179	8 48	12 18	3 30	9·12
11	1183	7 30	11 40	4 10	9·14
Dec. 9	1203	5 41	7 41	2 0	9·02
1921 Jan. 5	1207	6 39	8 12	1 33	9·10

We are indebted to Dr. A. A. Rambaut for communicating at our request the magnitudes of the nova on the above dates.

The photographs had to be taken as soon as possible after darkness had set in, owing to the fact that the nova was towards the west, and atmospheric refraction tended to move the image slightly in declination on the plate during the exposure; this had the effect of broadening the lines in the spectrum. There was therefore no gain in giving long exposures, as there was no sufficiently fine adjustment in declination on the telescope to correct this movement. Thus the long exposures first employed gave way to exposures of about two hours' duration.

In photographing the spectrum of the nova the telescope was run at as near sidereal rate as possible, a guiding star being kept on a wire in the illuminated field of view of the finder, corrections in right ascension being made occasionally with the electric slow motion.

Similar photographic plates to those employed in the earlier photographs were used, namely, Marion's "Record" (H and D 500).

Some of the above photographs are reproduced here in Plate 1, and two comparison photographs have been added: one of α Cygni, which the nova resembled in its early stages, and the other of a planetary nebula, *N.G.C.* 6210 (taken with the same instrument), to indicate the positions of the chief nebular lines. An attempt was made to produce a series of up-and-down enlarged photographs, but in some of the photographs sufficient contrast was not obtained to make a satisfactory plate.

Discussion of the Spectra.

The spectrum of the nova on each of the later photographs obtained was practically the same except for changes in relative intensities of some of the lines, but showed very great differences from the spectra obtained at earlier stages. The continuous spectrum, together with the absorption lines, had apparently disappeared entirely, and the spectrum was purely one of bright lines and bands. The most conspicuous of these were the hydrogen lines of the Balmer series and $\lambda 4686$, the "$\lambda 4640$" band, and the nebular lines N_1, N_2, $\lambda 4363$ and $\lambda 4068$. These were all very strong, and little doubt can be entertained of their identity. There were in addition, however, several rather faint nebulous bands, occasionally of great breadth, which were of doubtful origin. These rarely showed any well-marked maxima, and covered so wide an area (sometimes over 50 A.U.) that any assignment of possible origins to these bands can only be regarded as tentative. In view of other identifications, however, and the numerous coincidences which occur, it is thought that the most probable origins for the greater part of these bands is to be found in lines, or groups of lines, of nitrogen.

The following table gives the wave-lengths of all the bright

lines and bands observed in our photographs. In the case of some broader bands wave-lengths have been given of both edges; but these are only approximate, since the edges are in general so faint and nebulous as to make accurate measurements impossible. The probable origins of the more prominent lines have been inserted in the second column. The third column gives suggested possible origins of the fainter lines and bands. The identification of the two nitrogen lines in the "λ4640" band is due to Lunt and Fowler, and may be regarded as well established, though there are no definite maxima on our photographs to check the identification. The symbol p denotes an "enhanced" line.

Wave-Lengths and Probable Origins.

λ and Intensity of Bright Lines and Bands.		Probable Origins.		Possible Origins.		Remarks.
λ.	Int. (Dec. 9) (Max. 10).	Element.	λ.	Element.	λ.	
5007	7	neb.	5007			N_1.
4959	5	neb.	4959			N_2.
4861				pN	4867	H_β broad, and distinctly "winged" on red side.
				pN	4859	
	9	H_β	4861			
4750–4800				N	4803	Faint band. Not visible in some photos. Best seen in neg. of Oct. 25.
	1			N	4788	
				N	4780	
4686	5	H	4686			Strong. Well separated from λ4640.
4640				N	4643	Very strong band. Probable origins given by Lunt and Fowler. λ4643 doubtful.
	8	pN	4641			
		pN	4634			
4601	2			N	4602	Strong line. Separated from λ4640.
4542	1			H	4542	H_γ. Extremely faint.
4510–4530				N	4531	Faint band with slight max. near λ4516.
	1			pN	4524	
				N	4515	
				N	4511	
4430–4475		He	4471			Faint band. Max. near λ4471 with considerable extension towards violet.
	1			N	4447	
				N	4433	
4417	1			pTi	4417	Faint line.
{4363} {4341}				pN	4379	Strong band. Max. at λλ4363, 4341. Covers position of λ4379 which may be present.
	10	neb.	4363			
	6	H_γ	4341			

Wave-Lengths and Probable Origins—continued.

λ and Intensity of Bright Lines and Bands.		Probable Origins.		Possible Origins.		Remarks.
λ.	Int. (Dec. 9) (Max. 10).	Element.	λ.	Element.	λ.	
4302	1			pFe	4303	Faint band.
				pTi	4300	
4235	1			N	4242	Hazy band.
				N	4237	
				pFe	4233	
4201	1			H	4201	Extremely faint. Attributed to $H_{\delta'}$, but may be compound.
				pN	4200	
				pN	4196	
4102	6	H_{δ}	4102	pN	4103	N lines may be present, but masked by H_{δ}.
				pN	4097	
4068	2	neb.	4068			
4026	1			H	4026	V. faint. Possibly $H_{\epsilon'}$ + He.
3970	3	H_{ϵ}	3970			

Attention may be drawn to the group of lines near λ4640, which appear to vary in character in different novæ. In the present case there are undoubtedly three prominent and well-separated lines or bands at λλ4686, 4640 and 4601. Of these the band at λ4640 is the most prominent, followed by λ4686. The remaining line at λ4601 is considerably fainter. Lunt, in the case of Nova Aquilæ (3), found a continuous band, with maxima at λλ4686, 4650, 4641, 4634, and 4604. The maximum at λ4604 possibly corresponds with our line at λ4601, in which case the origin suggested (viz. nitrogen) would be rather doubtful. Adams and Pease in the later spectra of Nova Geminorum (2) described three well-separated lines at λλ4686, 4641, and 4610. There appears to have been no line at λ4601 or λ4604, and on our negatives there is nothing near enough to correspond with their line at λ4610.

On the presence of Nitrogen in Nova Cygni.

The work of Fowler * on the spectrum of nitrogen, together with Lunt's † observations of Nova Aquilæ (3), presents fairly conclusive evidence as to the presence of nitrogen in that star. An investigation was therefore made with a view to determine what nitrogen lines, if any, were present in Nova Cygni; and if the somewhat vague bands already mentioned could be attributed, at least in part,

* *M.N.*, 80, 692. † *M.N.*, 80, 519.

to that element. It was found that there were faint lines or bands in nearly all the positions indicated by the wave-lengths in Fowler's list. These were mostly rather nebulous; but the coincidences throughout the spectrum are rather striking, and in many cases the evidence seems to be strongly in favour of nitrogen as the origin. Both enhanced and unenhanced lines seems to be present, the strongest of the latter being the line at λ4601·66, which is suggested as the probable origin of the line already mentioned at λ4601 on our negatives. The stronger enhanced lines unfortunately occur, in many cases, so near to some strong broad line of hydrogen or nebulium that it is difficult to make a definite statement as to their presence or absence in the nova. The line at λ4867 is most probably present, since H_β is quite definitely "winged" on the red side. λ4859 may also be present, but is too near H_β to give any definite evidence. The lines at λλ4641 and 4634 have already been shown by Lunt and Fowler to be, most probably, the chief constituents of the "λ4640" band. The group of lines from λ4524 to λ4511 is represented in the nova by a comparatively strong band. There are distinct indications of a maximum near λ4515, showing that the nitrogen line at λ4515·04 is probably present, and the remaining lines of the group may also be concerned in producing this band. The next important enhanced line of nitrogen is at λ4379. This occurs near the nebulium line at λ4363, which is very strong and broad in the nova spectrum, extending well over the position of the nitrogen line. The latter may therefore be present in the nova, and its occurrence may account for the great breadth of the nebulium line. The region near λ4200 is rather underexposed in our photographs, but there is a faint rather broad line at about λ4201 which we attributed to $H_{8'}$. The nitrogen line at λ4200 may, however, also be present, and possibly also λ4196. The rather strong pair of enhanced lines at λ4103 and λ4097, if present in the nova, are masked by H_δ. Nothing definite can be said as to their presence or absence.

The above conclusions are embodied in our table under the heading "Possible Origins." If they are correct it will be seen that practically all the otherwise puzzling bands are accounted for, and the spectrum as a whole is greatly simplified. It is reduced, in such a case, to one of hydrogen, nebulium, nitrogen, and possibly helium, with perhaps a trace of the earlier enhanced metallic stage.

Variations in Relative Intensities of the Lines.

As already mentioned, all the spectra dealt with in this paper were very similar in character, but there were considerable variations in the relative intensities of the lines which are summarised below. In this table the relative intensities are given for each day, the intensities ranging from 10 to 1, 10 being the strongest line in each case. The change of the actual intensity of any line is thus not directly indicated.

	Intensities.							
				1920.				1921.
Date:	Oct. 24.	Oct. 25.	Oct. 26.	Oct. 27.	Nov. 5.	Nov. 11.	Dec. 9.	Jan. 5.
λλ								
5007	3	3	3	3	3	3	7	7
4959	1	1	1	1	1	1	5	4
H_β	10	10	10	10	8	10	9	8
4686	1	2	2	3	4	3	5	3
4640	8	8	8	8	10	9	8	5
4601	...	trace	...	...	...	...	2	2
4363	...	...	...	...	...	7	10	10
H_γ	7	6	6	6	7	7	6	5
H_δ	4	3	4	4	5	5	6	4

Comparison of the Nova with Planetary Nebulæ.

The more recent photographs which have been obtained of the nova show that the latter is now apparently assuming the character of a planetary nebula. The most characteristic lines in the spectrum of a typical planetary nebula are the Balmer series of hydrogen, the "Pickering" series (which is much fainter), λ4686, and the nebulium lines. It will be noticed that in our photographs the Balmer series and λ4686 are very strong indeed. The Pickering series is present, though faint (as in the nebulæ); and the nebulium lines are very prominent. The general resemblance to planetary nebulæ is thus very striking. At first sight the presence of nitrogen might appear to constitute an important difference; but it must be remarked that the nitrogen lines are rather faint, and are possibly dying out—as shown by the fading of the "λ4640" band. Also, in referring to Wright's list of nebular lines,* it is found that there are several lines given which might be attributed to nitrogen. The chief of these are at λ4097 (identified as N by Wright), λ4634 (attributed to "H II"), and λ4641 (no origin given), all of which are enhanced lines of intensity 10, 8, and 10 respectively, according to Fowler. The two last lines, together with one at λ4649 (C) in the same list, are in the positions indicated by Lunt as the maxima of the "λ4640" band in Nova Aquilæ (3). It appears therefore that the fading away of this band might result in the lines given by Wright.

Description of the Plate.

Four spectra of the nova are shown in this plate, and they were taken on October 25, November 5, December 9, and January 5 (1921). They are enlarged 3·7 times from the original negatives. At the top is reproduced the spectrum of α Cygni, the star the nova resembled at its earlier stage, and the last but one is the spectrum of the planetary nebula *N.G.C.* 6210; both of these

* *Publications of the Lick Observatory*, 1918, **13**, opp. p. 242.

Progressive Spectra of Nova Cygni III. (1920).

photographs were taken with the same instrument and adjustments as the nova negatives. On October 25 it will be noticed that the "λ4640" band is relatively strong, and the nebular lines weak. On November 5 the nebular lines N_1, N_2 and λ4363 have strengthened considerably, also λ4686, while λ4640 has slightly weakened. By December 9 all three nebular lines are very pronounced, also λ4686, but λ4640 has diminished in brightness. In the last-mentioned photograph several other bands are seen in the original negative, but are too faint to be reproduced in the illustration. On the photograph taken on January 5 of the present year, λ4363 is the most prominent line, followed in intensity by H_β and the nebular lines. λ4640 is considerably reduced in relative intensity, and also λ4686, but to a less degree.

The approximate wave-lengths of some of the stronger lines are indicated at the bottom of the plate.

Photographic Magnitudes and Effective Wave-Lengths of Nova Cygni (1920), *from Photographs taken at the Cambridge Observatory.* By W. M. Smart, M.A., and H. E. Green.

(*Communicated by Professor A. S. Eddington, F.R.S.*)

The photographic magnitudes of Nova Cygni were obtained by comparing the images of the Nova with those of γ Cygni and Boss 5026. The values of the magnitudes of the comparison stars adopted were those of *Harvard Annals*, 50, namely, 2·32 and 5·86 respectively. As the Zenith distances at which the Nova and comparison stars were observed were very small, no corrections for differences in atmospherical absorption were applied.

The photographs were taken with the Sheepshanks (Coudé) Equatorial. Over the object-glass was placed a parallel-strip diffraction grating for which the widths of strips and spaces are the same (0·37 cm.). The dispersion is such that the separation between the central image and the first-order image is 0·035 cm. For the grating, the theoretical difference of magnitude between the central and first-order images is 0·98. (Chapman and Melotte, *M.N.*, 74, 53.)

From a plate of five minutes' exposure on the Pleiades, the measures of the central and first-order images of 12 stars, ranging in magnitude from 2·84 to 6·66 (*H.A.*, 91), were combined to determine the constants in a linear relation connecting the magnitudes and the measured diameters, the theoretical magnitude interval being applied in the case of the first-order images. For purposes of magnitude determination, exposures of 20^s, in groups of 10, were made on the Nova and γ Cygni, and from September 26 of 1^m and 2^m on the Nova and Boss 5026. By means of the relation derived from the Pleiades plate, the differences of mag-

nitude between the Nova and the comparison stars were obtained from the measured diameters of the central and first-order images (the latter up to September 10 only in the case of the Nova). The results derived from the measures of the central images of the Nova and γ Cygni were in extremely good agreement with those derived from the first-order images. The means are shown in the table below. In the comparison of the Nova with Boss 5026, the central images only were measured.

The same comparison stars, both of spectral type F8, were employed in the differential determination of the photographic effective wave-lengths of the Nova. The value of the wave-length for type F8 which we adopted was 425 $\mu\mu$ (Lundmark and Lindblad, *Astrophysical Journal*, 46, 210). In addition to the exposures suitable for magnitude determination, further groups of exposures were obtained, ranging from 5^s to 50^s. The measured separation of the first-order images showed no systematic dependence on the exposure-times, and the means of the measures for all exposures on each night were accordingly taken. The effective wave-lengths tabulated below are the result of at least 20, and generally 40, exposures on the Nova and on the comparison star.

The results seem to indicate an irregular increase in wave-length from August 26 to September 18—from 423 $\mu\mu$ (type F5) to 433 $\mu\mu$ (type K),—and then a retrogression to 427 $\mu\mu$ (type G) at the beginning of October. Our results for August 26, September 7, 10, and 11, and the visual effective wave-lengths given for these days in *Urania Observatory Communications*, No. 1, exhibit the same general tendency. The large increase in the effective wave-length on September 18 was confirmed by re-measurement of the plate.

The observations were made about 9^h G.M.T.

Magnitudes and Effective Wave-Lengths of Nova Cygni.

Date.	Photographic Magnitude.	Effective Wave-Length.
1920.	m.	$\mu\mu$.
August 26	2·53	423·4
29	3·27	423·2
September 4	4·32	429·5
6	4·45	425·6
7	4·48	431·0
10	4·55	430·2
11	4·66	428·6
12	4·70	427·7
18	5·44	433·3
26	6·24	425·0
27	6·45	426·8
29	6·42	430·5
October 2	7·15	427·1

The photographs from August 26 to September 12 were taken by Mr. W. M. Smart, and from September 18 to October 2 by Mr. H. E. Green; the Pleiades plate was measured by both of us, and the measures of magnitudes and effective wave-lengths were made by Mr. H. E. Green.

Observatory, Cambridge:
1921 *January* 7.

On the Occurrence of the Enhanced Lines of Nitrogen in the Spectra of the Novæ. By W. H. Wright.

With reference to the extremely interesting work of Professor Fowler on the enhanced spectrum of nitrogen,* I may perhaps be permitted to state that several months ago I received a letter from Mr. Baxandall on the same subject, as related in a note at the end of Professor Fowler's paper, in which attention was drawn to the enhancement, under conditions of intense electrical excitation, of certain of the nitrogen lines. Such observations are of great assistance to those who are endeavouring to interpret the spectra of the novæ and the gaseous nebulæ, and it gives me pleasure, as one interested in those subjects, to acknowledge the assistance, and to be instrumental, with the aid of photographic observations of some of the nova spectra, in furnishing evidence which perhaps further justifies the identities which they have suggested.

As a step preliminary to the discussion of these identities it may be well to reproduce in part, for convenient reference, Professor Fowler's table of the enhanced spectrum of nitrogen. The original table is limited to the spectral region of $H_\beta - H_\epsilon$. The following list contains all lines of intensity 4 and over. The figures are abbreviated by being struck to the nearest tenth of an angstrom.

TABLE I.

(R).	i.	(R).	i.
4097·5	10	4515·0	6
4103·5	8	4634·3	8
4200·2	4	4640·8	10
4379·3	10	4867·3	4
4511·1	5		

Comparison with the "Nebular" Stage of the Nova Spectrum.—The foregoing excerpt from Fowler's table includes all the lines referred to by Mr. Baxandall. The first, second, and fourth lines were announced as enhanced or "abnormal" by Lockyer, Baxandall, and Butler in 1909. The remainder have only recently become available through the publications and letter referred to. Several of the brighter of these lines have been identified with a high degree of probability in the spectra of the nebulæ, and they have almost unquestionably occurred in a number of novæ during the

* *M.N.*, 80, 692 (1920).

"nebular" stage. The first on the list, which is perhaps the most characteristic, as it was the earliest to be detected by the laboratory workers, occurred in the spectrum of *Nova Geminorum* (2) * and in that of other objects, including *Nova Aquilæ* (3), as already reported by Dr. Lunt. Its presence is, in these instances, manifested by a conspicuous margin to the more refrangible edge of the H_δ band. In the star in *Aquila* the line anticipated the complete conversion of the spectrum to the nebular stage, but in *Nova Geminorum* it was certainly present only after that status had been reached, when it became well established as a feature of the spectrum. Fowler calls attention to the fact that a number of other lines recorded in his table were doubtless measured by Lunt in the spectrum of *Nova Aquilæ* (3); and as these, and perhaps a few others, were present in the spectrum of *Nova Geminorum* (2), it may not be out of place to refer to them. For the purposes of the present note, it will suffice to single out for discussion one of our numerous tables of the spectrum of *Nova Geminorum*, made from two spectrograms which yield practically identical results. The observations which serve as the basis of Table II. were made about a year after light maximum and while the spectrum was in the nebular stage. The table records the mean results from the two plates. Except where noted, the wave-lengths refer to the details of emission bands. Measurements of a single band—either simple or compound—are set off in groups. Very faint bands are indicated by the abbreviation "v. ft." preceding the initial measurement of the band. In view of the fact that the character of a nova spectrum is such that its measurement calls, at times, for the exercise of the observer's judgment, it seems proper to state that these measurements were made several years ago; that is to say, before a knowledge of the enhanced spectrum of nitrogen was available.

TABLE II.

Table of Wave-Lengths, Nova Geminorum (2), 1913 *Feb.* 10–*Mar.* 6.

v. ft.	3964±	edge.
	3980±	edge.
v. ft.	4065	edge.
	4083	edge.
	4090	edge.
	4091·3	maximum.
	4093·7	dark line.
	4095·9	narrow maximum.
	4114	edge.
v. ft.	4185±±	edge.
	4210±±	edge.
	4331	edge.
	4334·0	v. sharp maximum.

* *Proc. Nat. Acad. Sci. Am.*, **1**, 596 (1915).

TABLE II.—*continued.*

	4354	beginning of brighter part.
	4356·4	narrow maximum.
	4364·5	centre of brighter component.
	4373·5	maximum.
	4376	end of brighter part.
	4391±	end of very faint extension.
v. ft.	4466±	edge.
	4482±	edge.
	4501	beginning of faint extension.
	4509	beginning of brighter part.
	4517	centre of brighter part.
	4525±	end of brighter part.
	4549±±	end of faint extension.
	4595	edge.
	4607	centre.
	4618	edge.
	4621·7	dark band, or space separating two bright bands.
	4626	edge.
	4630·4	dark line bordering brighter part of band.
	4633·2	principal maximum.
	4638	minimum.
	4649	minimum.
	4654	end of brighter part.
	4662	end of very faint extension.
	4676	edge.
	4678·5	maximum.
	4681·1	fine dark line.
	4687·8	centre of band.
	4697	maximum.
	4699	edge.
	4724	v. v. faint extension to here.
	4852	edge.
	4853·9	maximum.
	4863·3	centre.
	4872·5	maximum.
	4874	edge.
	4949	edge.
	4951·6	maximum.
	4961·1	centre.
	4970·0	maximum.
	4973	edge.
	4996	edge.
	5000	maximum.
	5008·0	centre.
	5018·4	maximum.
	5021	edge.

For the interpretation of Table II. it should be stated that the spectrum consists of emission bands about 23 angstroms wide. Within each of these bands and near the violet edge is a sharp narrow maximum, while close to the opposite edge is another maximum, somewhat similar to the first but broader and less well defined. The centres of the bands are of slightly greater wave-length than the lines with which they are generally identified. The procedure will be to determine what may be called the band *characteristics* from those radiations whose normal wave-length is known, and with these data to proceed by the inverse process to evaluate the wave-lengths of the bands of unknown origin. The "characteristics" which we shall have occasion to use in the present instance are the displacement of the sharper maximum and those of the centre and edges of the band. Assuming these displacements to be proportional to the wave-lengths, the following expressions have been derived from the known bands in Table II. :—

Displacement of narrow maximum . .	$-15{\cdot}5\lambda \times 10^{-4}$	
,, of violet edge . . .	-21λ	,,
,, of red edge	$+28\lambda$	,,
,, of centre	$+ 1{\cdot}6$A	

where λ represents in each case the wave-length of the measured feature.

The use of the first relation offers the most certain means of estimating the normal wave-length of a band, provided the maximum referred to is measurable, since the equation reproduces the measured displacements of the known bands to within a tenth or two of an angstrom. Next in order of reliability is the determination by measurement of the centre of the band. The edge measurements furnish, especially in the cases of faint bands, only approximate results, and it is apparent that in those instances the corrections should be less than the ones derived from the comparatively strong bands which serve as the basis of the foregoing equations. For instance,—the extremely faint band at 4474A—or, corrected to normal, 4472A,—undoubtedly due to helium, records a width of only 16A, while well-exposed bands are about 23A wide. This should be borne in mind in applying corrections to the measured positions of the edges of faint bands, and I have endeavoured to call attention to the fact, in instances where it seemed appropriate, by adding a minus sign in parentheses to those corrections which it is believed should be reduced.

We are now in a position to derive the normal wave-lengths of some of the bands indicated in Table II. Referring to the reduction form set forth in Table III., the entries in the first column describe the feature measured; the second column records the position, transcribed from Table II.; the third gives the appropriate correction as computed by the foregoing linear equations; and the fifth the inferred normal wave-length of the radiation in question. The fourth column is reserved for the tabulation of individual

results where more than one independent determination of position is available. For the purpose of economising space, bands of known origin (including the nebular bands N_1 and N_2) have been omitted from Table III.

TABLE III.

Reduction to Normal Wave-lengths.

	Measured.	Corr.		Normal.	Prob. Origin.		Remarks.
Centre	4074	− 1·6	...	4072	neb.	4069–76	V. ft.
Violet edge	4090	+ 8·6 (−)	4098−	4097·6	N	4097·5	Fairly bright.
Maximum	4091·3	+ 6·3	4097·6				
Red edge	4114	−11·5 (−)	...	4103+	N	4103·5 *	
Violet edge	4185±±	+ 8·8 (−)	...	4193±±	N	4195·8(?)	V. ft.
Red edge	4210±±	−11·8 (−)	...	4199±±	N	4200·2†; Hδ′ 4200	V. ft.
Red edge	4391	−12·3 (−)	...	4379+	N	4379·3	V. ft.
Violet edge	4501	+ 9·4 (−)	...	4510−	N	4511·1	V. ft.
Centre	4517	− 1·6	...	4515	N	4515·0‡	Rather ft.
Red edge §	4549±±	−12·7	...	(4537±)			
Centre	4606·7	− 1·6	...	4606	neb.	4610± (Campbell)	
Violet edge	4626	+ 9·7 (−)	...	4635−	N	4634·3	Rather ft.
Maximum	4633·2	+ 7·2	4640·4	4640·5	N	4640·8	Fairly bright.
Red edge	4654	−13·0	4641				
Red edge	4662	−13·0 (−)	...	4650+	C	4647·6–50·8	V. ft.
Red edge	4724	−13·2 (−)	...	4711+	neb.	4711	V. ft.

* There is of course some doubt whether the measurements indicate the presence of this nitrogen line, since Hδ, of wave-length 4101·9, is very close; yet the same effect is found in the spectrum of *Nova Aquilæ* (3) as has been noted by Lunt, and the measurements correspond more closely with the nitrogen line than with the other.

† Hδ′ and the nitrogen line nearly coincide. It is doubtful, from the circumstance that Hβ′ has not been observed, whether the nova band can be due to Hδ′ alone.

‡ In the discussion which followed the presentation of Professor Fowler's paper at a meeting of the Royal Astronomical Society, as reported in the issue of the *Observatory* for July, Lieut.-Colonel Stratton referred to a group of iron lines as possibly vitiating the identification of this line proposed by Fowler. While the point was probably well taken with respect to the occurrence of the line in the comparatively early spectrum of *Nova Aquilæ* (3), it cannot well be interposed as an objection in the present instance, because the observations were made long after the disappearance of the iron lines from the spectrum of the star.

§ This is the gradually fading termination of an extremely faint extension to the compound band composed principally of the two preceding lines (see Table II.). Fowler gives a group of five faint enhanced nitrogen lines between 4518 and 4546A, and it does not seem improbable that the extension is due to them. Hγ′ (4542A) is also near here, but its presence is doubtful, because, as indicated in a preceding footnote, the series of lines to which it belongs is faint in the spectrum of the nova.

The table shows a very good correspondence between the spectrum of the nova and the enhanced spectrum of nitrogen, quite as good as one could hope for when the difficulties inseparable from observations of this kind are considered, and the identifications may doubtless be regarded as established with a high degree of probability. All of the lines in Table I. appear to be present except 4867A, and this is so close to Hβ that it would, in view of its faintness, hardly be expected to appear. There are, however, two anomalies to which attention should be drawn. The first is the comparative faintness of the nova band at 4379A, and the other is the behaviour of some of the lines in question in the nucleus of N.G.C. 2392 and in other Class O stars.

The first of these is probably not a serious matter. In the excellent illustration which accompanies Professor Fowler's article, 4379A seems to be broader and hazier than the other enhanced radiations, and may possibly show peculiarities of behaviour, though of course judgment on such a matter can be passed only by those engaged in the laboratory investigations; but in any case changes in the relative intensity of lines cannot be regarded as invalidating a general identification of the nature of the one proposed.

The second of the two peculiarities is the occurrence of one of the strongest of the lines under discussion, 4097A, as dark, and two others, 4634 and 4641A, as bright, in the same spectrum. The phenomenon has been noted in the nucleus of the nebula just referred to; it appears from Paddock's measures of the spectrum of the Class O star A.G.C. 22748 to be exhibited there, and is doubtless of common enough occurrence. It seems probable that the lines in question have a common origin in the novæ, the nebulæ, and the Class O stars, which is the reason for bringing the latter into the discussion. The possibility suggests itself that their opposite behaviour, *inter se*, in the stellar spectra is an effect of wave-length, paralleling the association of bright and dark hydrogen lines in the spectra of *Alcyone* and other objects which show the upper members of the series dark and the lower ones bright. Whatever the merits of this or any other explanation, the points raised can for the present hardly be urged as critical, as against the proposed identification, though they should be held in mind in any consideration of it.

Comparison with the "4640" Stage of the Nova Spectrum.

The foregoing observations were made while the spectrum was in the nebular stage and have no direct bearing on the so-called "4640" phase. The latter is ordinarily interposed between the "bright band" or enhanced iron emission condition and the nebular condition of the spectrum, and the importance of getting at some understanding of its nature has been felt by everyone who has given serious thought to the problems raised by the temporary stars. There were a number of curious developments

in the spectrum of *Nova Geminorum* (2) which do not appear to have been described heretofore; and as they refer to the 4640 spectrum, and, possibly, also stand in some relation to the new spectrum of nitrogen, it will be well to give some account of them. These developments involved the reversion on at least two occasions to the "4640" stage after the "nebular" stage had been reached, and it is with the phenomena associated with these cut-backs—more especially the second—that the remainder of this communication deals.

The spectrum of the nova entered the nebular stage in April or May of 1912. On May 12 the 4640 band, which had previously been broad and diffuse, was comparatively definite in outline and hardly wider than the other bands. The usual nebular radiations were present; in particular, 4686A was strong. Fifteen days later the 4640A band was again broad and diffuse, and 4686A had disappeared, there being a shallow minimum in its place. A broad hazy band of the same form as 4640A spread itself over the H_δ region. That observation was the last before the star was lost in the west. By August, when it again came under observation, the nebular characteristics had been re-established and the usual bands, including 3445 * and 4686A, were strong. Barring certain irregularities, that cannot be referred to here, the nebular character was maintained until October 31. On that date the bands were perfectly regular, 4634–40 being quite as definite as its composition would permit. At some time between then and November 18 a profound alteration occurred in the spectrum. This was six months after the nebular stage was first established. A plate of the visible region was taken on the latter date, and one of the ultra-violet spectrum was secured three days later. As these spectrograms conform with each other in the region of overlap, they will, for simplicity, be described together.

Four broad and hazy bands are present in approximately the positions given in Table IV. These wave lengths are extremely

TABLE IV.

Wave-length.	Width in Angstroms.	
	Nov. 18.	Nov. 21.
3412±	...	63±
3484±	...	63±
4103±	...	82±
4640±	90±	160±

* In the paper as originally communicated to the Society, the wave-length of this line was erroneously given as 3426A. There are lines in the spectra of the nebulæ at both 3426 and 3445A, and the nova radiation in question was wrongly identified, notwithstanding the fact that I had previously measured and recorded its position correctly. The measured positions of the edges of the nova band are 3436·1 and 3453·4, giving 3445A as the position of the centre, which agrees with the nebular wave-length referred to. In the nebulæ there are fainter lines at 3313 and 3342 which commonly occur with 3445A, and of these the stronger, at 3342, is present in the nova, the other member of the group probably being too faint to record.

uncertain; they may be in error five angstroms, or even more. The bands present broad and diffuse maxima which fade gradually on each side to insensible intensity. It is a difficult matter to estimate their breadth, for this, from the structure of the bands, depends upon the length of exposure. The widths given in the third column of the table are based on the measurement of the ultra-violet spectrogram, which is over-exposed in the neighbourhood of 4640A. That of the fourth band, as measured on the plate of the visible region, secured a few days earlier, is 90A. The plate is weak there, and the disparity in the measured widths probably results from the difference in density of the two records. In structure the new emissions are totally unlike the characteristic nebular bands, which have well-defined edges and are about 25A wide. Most of the nebular bands remain in the spectrum, but the two at 3445 and 4686A have completely disappeared, their positions being in fact marked by minima of intensity.*

On November 22 the same condition persisted; by the 26th the new radiations, though present, were fainter, and both of the nebular bands noted as having been extinguished had reappeared in their original strength. A day later the spectrum was apparently normal. Observations made at intervals during the succeeding twelve months showed no return of the spectrum to the anomalous condition just described.

In an attempt to trace similar changes in other novæ a pronounced case of the 4640 stage was encountered in *Nova Geminorum* (1) (Turner's nova of 1903) as photographed by Reese and Curtis.† The plates reproduced with their description of the spectrum exhibit a well-developed 4640 band and another of similar structure near 4100A, which they have referred to as H_δ. That designation was no doubt used merely for the purpose of indicating the position of the band, and not to suggest its identification as a hydrogen line, for it is patent from a glance at the plate that the H_δ hydrogen line can have little to do with the production of the band in question. We have then in that star, as in *Nova Geminorum* (2), the subject of the present note, bands at approximately 4100 and 4640A, which correspond closely in position with the two strong doublets in the new spectrum of nitrogen, and it is perhaps significant that Reese and Curtis record a faint broad maximum at 4378, which is close to the nitrogen line 4379A, though no band in that position was found in *Nova Geminorum* (2). It is fortunately possible to combine with these observations some ultra-violet spectrograms of the star made by Perrine.‡ Perrine's apparatus was inadequate, and his results are subject to a large systematic error; but when this is allowed for, it seems quite certain that, coincident with the occurrence of broad bands at 4640

* It may be worthy of remark that the nebular band at 3995A, for which a nitrogen origin has been suggested, maintains the typical nebular structure. The corresponding nitrogen line is one of the strongest in the spectrum of that element, but is not noted by Fowler or Baxandall as enhanced.

† *Lick Obs. Bull.*, 2, 62 (1903).

‡ *Loc. cit.*, pp. 58–131.

and 4100A, there was a strong one at 348$\mu\mu$, which gave way to another at 343$\mu\mu$ when the spectrum became nebular.

The tentative conclusion which I have drawn from these observations is that the spectrum which gives character to the "4640 stage" of the nova development consists of broad diffuse bands approximately in the positions indicated in Table IV.

This group of bands has been known here for a number of years, and has been sought in the spectra of various celestial objects. With the exception of the first member they are apparently emitted as prominent radiations by the Class Oc star B.D. +36° 3987. A nitrogen origin naturally suggested itself, since the strongly enhanced nitrogen doublet 4097–4103A lies close to the third band on the list, and there are numerous nitrogen lines near 4640A, though none of these were known to be enhanced. With the announcement by the English observers of the peculiar behaviour of the doublet in that neighbourhood, it becomes possible to associate nitrogen, at least tentatively, with the 4640 spectrum, and the surety of the identification would be augmented if enhanced nitrogen lines were found near 3412 and 3484A.

Summary.

1. The spectrum of *Nova Geminorum* (2) very probably exhibited, during the nebular stage, the stronger lines of the enhanced spectrum of nitrogen as recorded by Baxandall and Fowler.

2. In that star the "4640" stage was recurrent after the "nebular" stage had become established, the last observed reversion to the earlier type taking place six months after the commencement of the nebular period.

3. The "4640" type of spectrum was marked by the formation of broad, hazy bands near 3412, 3484, 4103, and 4640A, and by the total extinction of the nebular bands 3445 and 4686.* A tentative identification of the two hazy bands of greater wavelength as enhanced radiations of nitrogen appears permissible, pending the *placing* of the two in the ultra-violet.

Further Note on Enhanced Lines of Nitrogen.

By A. Fowler, F.R.S.

In the foregoing paper Mr. Wright has brought forward additional evidence in favour of the identification of certain lines in the spectra of novæ with enhanced lines of nitrogen, and in connection with the peculiar spectrum exhibited by Nova Geminorum (2) in 1912 November, has drawn attention to the need for further observations of the laboratory spectrum in the ultra-violet.

* These radiations have a somewhat related occurrence in the spectra of the planetary nebulæ (*Pub. Lick Obs.*, 13, 256 (1918)).

The table given in my previous paper * covered the range H_β to H_ϵ, but photographs of the more refrangible parts of the spectrum had also been obtained, and the wave-lengths of the lines have since been determined.

The peculiarity in Nova Geminorum (2) noted by Wright involved the disappearance of the characteristic lines 3426 and 4686 A, and their replacement by four broad hazy bands at approximately 3412, 3484, 4103, and 4640, with an uncertainty amounting to at least 5 angstroms. These bands appear to be specially characteristic of the "4640" stage in the development of novæ, and in indicating the probability that 4103 and 4640 represent the blended pairs of enhanced nitrogen near these positions, Wright points out that the evidence would be greatly strengthened if enhanced lines of the same element were also found near 3412 and 3484.

The extended observations of the laboratory spectrum show no enhanced nitrogen near 3412, but there is a prominent triplet near the second position, and there are no other lines of importance between this and H_ϵ.† The wave-lengths of the additional lines are given in the following table, which also includes particulars of the other two pairs, and indicates their relation to the nova spectrum :—

Enhanced Nitrogen.	Intensity.	Nova.
3478·84	7	3484±5
3483·13	5	
3485·05	3	
4097·48	10	4103±5
4103·54	8	
4634·34	8	4640±5
4640·82	10	

The agreement is as close as can be expected from the nature of the nova bands, and there can be little doubt that three of the four bands characterising the peculiar spectrum of the nova are to be accounted for by enhanced nitrogen. The band at 3412 is not represented in the enhanced spectra of nitrogen, oxygen, carbon, silicon, or sulphur, and no origin for it can at present be suggested.

With reference to Mr. Wright's remarks on the line 4379, an examination of additional photographs has shown that this line is sometimes much less intense than 4640. Mr. Baxandall has also informed me that while this line is sometimes the strongest in the enhanced spectrum, it is comparatively insignificant in others. The apparent absence of 4379 from the nova spectrum in some cases therefore furnishes no evidence against the identification of the other bands.

* *M.N.*, **80**, 692 (1920).

† The strongest line in this region is one of about intensity 3 at 3771·20.

The Displacements of the Hydrogen Absorption Lines in the Spectrum of Nova Geminorum in March 1912, *with Remarks upon their Interpretation.* By W. H. Wright.

In a recent number of these publications * Colonel F. J. M. Stratton summarises the conclusions arrived at in his very extensive and important study of the spectrum of *Nova Geminorum* (2). The full account of the work is promised as part of the *Annals* of the Solar Physics Observatory. While the evidence on which his conclusions rest will not be available until the appearance of the larger publication, it seems appropriate to call attention to some observations which are apparently not in complete agreement with those that serve as the basis of one of Colonel Stratton's most important deductions. I refer to the interpretation of line displacements as the effect of velocity in the line of sight. Colonel Stratton's opinion on this much discussed matter is expressed as follows:—

"Explanations of the main phenomena in terms of electric or magnetic fields have failed, and the evidence is *decisive* for the interpretation of the observed results in terms of the Doppler effect. *The displacements vary directly as the wave-lengths*, and are apparently independent of the element concerned. . . ."

I have taken the liberty of italicising the parts of the quotation to which the present paper, in the main, relates.

Colonel Stratton is not alone among observers of temporary stars in holding such an opinion. Dr. Joseph Lunt has, in his investigation of the spectrum of *Nova Aquilæ* (3), been led to accept the same interpretation of the displaced lines.† In view of the formative influence which the important contributions of these observers must have on general scientific opinion respecting the novæ, it seems advisable to present a brief account of the present observations rather than to await their publication as part of a general description of the spectra of the temporary stars which the Lick Observatory plans to issue.

The view that the displacement of absorption lines and other spectral features of the novæ are due to velocity, although taken arbitrarily by some astronomers in the case of *Nova Aurigæ* (1892), rests primarily on the assumption that these displacements are exactly proportional to the wave-lengths of the lines concerned. It is probably not necessary to dwell upon the absolute dependence of that theory on the displacement law, nor to point out the serious consequences to it of any considerable departure of the displacements from strict proportionality to wave-length.

That the displacements do, in fact, follow approximately the law of proportionality was, I think, first noted in the spectrum of *Nova Persei* (2),‡ and the rule has been generally confirmed in more recent novæ; in so far, that is, as it is possible to establish

* *M.N.*, 80, 540, 1920.
† *M.N.*, 79, 417, 1919.
‡ *Lick Obs. Bull.*, 1, 46, 1901.

a numerical relation of the sort within the restricted range of wave-lengths usually covered by the measurements of these spectra, which are in their greater number made in the blue and violet regions of the spectrum. Particularly favourable opportunities to extend the range of observation were presented by the spectrum of *Nova Geminorum* (2) on the 22nd and 23rd of March 1912, and a somewhat less satisfactory one on March 30. On the earlier dates the dark hydrogen lines or bands were double, and though broad were definite, and lent themselves well to accurate measurement. On March 30 they were in some respects equally good, but were quite complex, and on the low dispersion plates the resolution was not sufficient to separate some of the close pairs. On both the 23rd and 30th the spectrum was photographed from the ultra-violet to the red, and measurements of the hydrogen lines are available from near the limit of the Balmer series to Hα. In order to indicate in advance the direction in which this discussion leads, I venture to anticipate its conclusions and state that on March 22–23 the displacements showed an appreciable departure from the law of proportionality, while on March 30 the results are indeterminate; as for other times, while absorption lines were of course present throughout the early history of the nova, they were not in general measurable to the degree of accuracy requisite for this inquiry.

Observations of 1912 *March* 22–23.—The observations of March 22 were made with the single-prism spectrograph which covers the blue and violet regions of the spectrum. They consist of three plates of different exposure which give excellent records of the spectrum from H$_\theta$ to H$_\beta$ (3798–4861A). The plates show the very interesting series of double dark hydrogen lines which first became conspicuous at this time, and suggested at once the advisability of extending the observations into the ultra-violet and visible regions of the spectrum. This was done on the following night. The observations of the 23rd were made with the quartz spectrograph attached to the Crossley reflector, and with a single-prism glass instrument adjusted to the visible spectrum and attached to the 36-inch refractor. Two spectrograms of the ultra-violet and one of the visible region were secured, which together furnish a record from about 3250 to 6875A. The plates offer the basis for a fairly comprehensive set of measurements of the hydrogen displacements on March 23, and for that reason they will be discussed at once, and the results will then be carried back and checked within the restricted range of the observations of the preceding day.

Before referring to the numerical data, I wish to call attention to the fact that the ultra-violet spectrograms are on photographic films, and that the field of the spectrograph has a high inclination to the camera normal.* For these reasons one feels surer of his ground in the use of this apparatus if there are checks against

* For a description of the ultra-violet spectrograph, see *Lick Obs. Bull.*, 9, 52, 1917.

systematic error. Fortunately, the spectrum of the nova was observed elsewhere on the same day with standard instruments, and I have availed myself, for the purpose of a check, of the observations of Furuhjelm,* on account of their reach into the ultra-violet. In Table I., which records the measured positions of the hydrogen dark bands, his observations are given in the

TABLE I.

Hydrogen Dark Bands, 1912 *March* 23.

Normal.	Component I.				Component II.			
(Rowland.)	L.O.	Pots.	Δλ. Obs.	Δλ. Comp.	L.O.	Pots.	Δλ. Obs.	Δλ. Comp.
π 3691·7	...	...	...	...	3675·5	...	−16·2	−16·5
ο 3697·3	(3688)†	...	...	...	3681·2	...	−16·1	−16·5
ξ 3704·0	(3696)†	...	...	...	(3688)†	...	...	...
ν 3712·1	...	...	...	...	(3696)†	...	...	...
μ 3722·0	3712	...	−10·0±	−10·0	3705·2	...	−16·8	−16·7
λ 3734·5	3725	...	− 9·5±	−10·1	3717·3	...	−17·2	−16·7
κ 3750·3	3740	...	−10·3±	−10·1	3733·6	...	−16·7	−16·8
ι 3770·8	3761·2±	...	− 9·6	−10·2	(3753)‡	...	...	...
θ 3798·1	3787·9	...	−10·2	−10·3	3781·2	...	−16·9	−17·1
η 3835·6	3825·0	...	−10·6	−10·4	3818·1	18·1	−17·5	−17·3
ζ 3889·2	3878·4	78·8	−10·8	−10·5	3871·6	71·5	−17·6	−17·6
ϵ 3970·2 §	(3958·5)	58·8	(−11·7)	−10·8	3951·7	51·7	−18·5	−18·1
δ 4101·9	4090·9	90·8	−11·0	−11·2	4083·0	82·9	−18·9	−18·8
γ 4340·6	4328·2	28·7	−12·4	−11·9	4320·5	20·4	−20·1	−20·2
β 4861·5	4847·7	...	−13·8	−13·5	4837·9	...	−23·6	−23·4
α 6563·0	(6544±)‖	....	(−19)	−19·0	6528	...	−35	−35·0

* *Publ. Astroph. Obs. Pots.*, 22, No. 68, 24, 1913.

† Absorption lines occur here, but there are conflicts between line I. of a member of the Balmer series and line II. of the member following it; that is, the interval between Components I. and II. is approximately equal to the difference in wave-length of successive members of the series. The measured positions probably represent Components II., since they are the stronger, but the wave-lengths have not been used in the calculations.

‡ There seems to be a dark companion on the more refrangible edge of this line. It differs in appearance from the other stellar lines in the vicinity.

§ The H calcium line at 3968·6A disturbs the position of Component I. but hardly affects that of II. The reason is that for hydrogen Series II. is the stronger, while for calcium—as shown by the K line—the reverse is true. H calcium and Hϵ overlap, and here the absorption bands are about equally intense, the calcium wave-length dominating in I. and that of hydrogen in II. For neither series has the line been used in the determination of constants.

‖ Component I. is not certainly present. The position given is that of a suspected line bordering the brighter portion of the emission band. From here a very faint wing or extension of the bright band extends toward the violet and is terminated by the strong and definitely measurable absorption line at 6528A.

column headed "Potsdam." It will be seen that systematic error, if it exists at all, is almost negligible. The mean of the residuals (L.O. – Pots.) is $-\cdot 3$A for Component I. and $+\cdot 06$A for II., or a general average of $-\cdot 1$A.* The lines in Table I. to and inclusive of H_γ were measured on the spectrograms made with the quartz instrument, the remaining two on the plates of the visible region. I should perhaps have stated, in explanation of Table I., that the terms Components I. and II. designate the absorption bands pertaining to each member of the Balmer series, I. being the least displaced.

It will be remarked that the displacements $\Delta\lambda$, although they increase with the wave-length, do not vary in direct proportion; if they are plotted against wave-length the points defined do not lie on a straight line passing through the origin. As this is particularly apparent with respect to the second series, that will for the moment claim our attention. The upper part of fig. 1 is a plot of the displacements.† The points lie approximately on a straight line, but one which if produced toward the left will miss the origin ($\lambda = 0$, displ. $= 0$). The equation representing this line,

$$\Delta\lambda = -10^{-4} \times 63\lambda + 6\cdot 6 \quad . \quad . \quad . \quad (1)$$

satisfies the observations well enough, but the form is objectionable because it contains a term independent of the wave-length, which it would be difficult to interpret for the value $\lambda = 0$. Of course one would not be justified in making an extrapolation of that magnitude, but, in view of the high degree of probability that the true curve, whatever its analytical expression, passes through the origin, it seems preferable to accommodate the observations by the introduction of a quadratic rather than an absolute term. Such a procedure leads, in fact, to a more satisfactory representation of the observations than that of equation (1), and the expression

$$\Delta\lambda = -10^{-4} \times 33\cdot 6\lambda - 10^{-8} \times 30\lambda^2 \quad . \quad . \quad (2)$$

has been adopted as representing the displacements of Series II. The computed displacements are given in the last column of the table, and the curve is represented by the solid line in the upper section of fig. 1. The broken line indicates the best representation of the observations on the assumption that the displacements

* After this comparison was made it was found that on March 22 the Potsdam results showed a slight systematic difference from the Lick Observatory measurements with the glass or standard spectrograph (L.O. – Pots. $= -0\cdot 35\pm$). The displacements of Series II., as measured on the ultra-violet plates (from $H\gamma$ to the ultra-violet), may therefore be $-\cdot 36$, $-\cdot 06$, or $\cdot 4$A too small numerically, as compared with measures with our glass spectrograph. This is a matter of little consequence here, but it accounts in effect for the systematic correction found necessary in carrying back these results of March 23 to the measures of March 22, which were made with the glass prism.

† In drawing the figure it has seemed natural to measure the displacements *upward* although they are algebraically *negative*. This should be borne in mind in interpreting the signs of the coefficients.

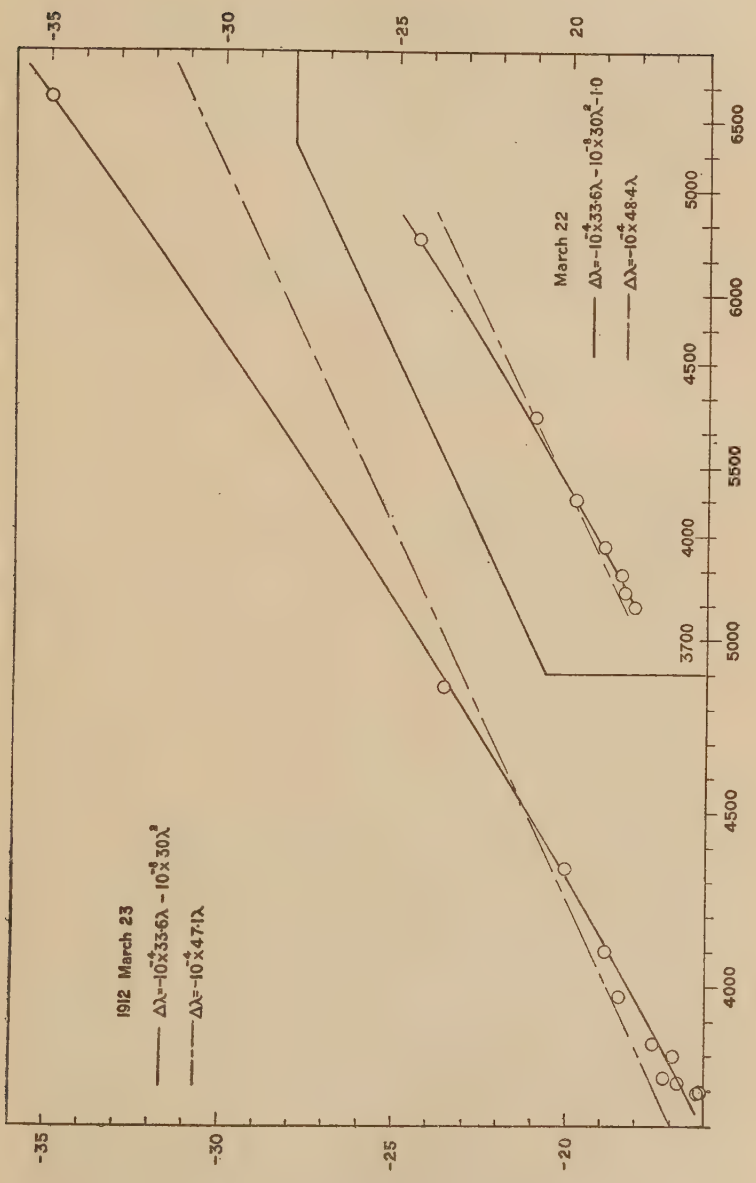

FIG. 1.—Wave-length—Displacement Curve. Series II. of Dark Hydrogen Bands.

are proportional to wave-length. For those who value the least squares criterion for conformability, it may be stated that the sums of squares of residuals for the curve and for the straight line are 0·85 and 24·2 respectively.

Series I.—In the lines of Series I. the displacement is much more nearly proportional to the wave-length. The quantities in column 6 of Table I. are computed by the formula

$$\Delta\lambda = -10^{-4} \times 24{\cdot}4\lambda - 10^{-8} \times 7\lambda^2 \quad . \quad . \quad (3)$$

It will be remarked that the coefficient of the term of the second degree is proportionally less than in equation (2), and if we omit H_aI, the measurement and in fact the existence of which is uncertain, the law of direct proportionality represents the remaining observations almost as well as equation (3). Casting out that line and taking the factor best adapted to those remaining, we have

$$\Delta\lambda = -10^{-4} \times 27{\cdot}4\lambda \quad . \quad . \quad . \quad (4)$$

The sum of the squares of the residuals using this relation is ·185, as against ·129 by equation (3), so that it gives almost, though not quite, as good representation.

Having ascertained the displacement relations for the extensive region of spectrum available for March 23, we may now examine the observations of the preceding day to see whether, within their more restricted range, the same law holds. Inasmuch as the law for Series I. is rather indeterminate, we shall in what follows consider only the lines of Series II.

There are available for purpose of comparison observations made at Mount Wilson,* at Ottawa,† and at Potsdam,‡ as well as those secured here. The displacements of Components II., corrected in some instances, as will be explained, are given in Table II. in ordinary type. A preliminary correction is required in order to bring all the data to the same time of observation, due to the fact that the position of the dark bands changed between March 22 and 23. The change is part of a general drift of the absorption lines toward the red, which appears to have been arrested, temporarily at least, on March 23. The difference between the wave-lengths on the two days was about ·46A, and both the Potsdam and Ottawa results were corrected, before entering them in the table, to reduce them to the time of the Mount Hamilton observations. As thus recorded, the several groups exhibit small systematic differences, and the plan has been adopted of correcting the observations of each group by the mean difference between it and that of Mount Hamilton. A little reflection will, I think, justify this procedure if the propriety of adopting it is not at once apparent. What we seek is the nature of the law of variation, and that is hardly affected by the small systematic corrections which have been applied. On the other

* *Astroph. Jour.*, 36, 293, 1912.
† *Publ. Dom. Obs.*, 1, 159, 1912.
‡ *Loc. cit.*

hand, were we to omit these corrections the systematic differences of the groups might introduce irregularities depending on the particular distribution of the lines within them. In the present instance it happens that the corrections do not sensibly affect any of the final means, but the system is adopted as being theoretically preferable to the striking of a direct mean. The corrections are −0·3, +0·3, and 0·0A for Potsdam, Ottawa, and Mount Wilson respectively. Applying these in the first two instances, we have the figures recorded in italics. The eighth column of Table II. contains the means of the four groups of observations. The quantities are plotted in the lower part of fig. 1. The solid line in the figure represents the curve deduced on March 23, displaced parallel to itself by a uniform correction of −1·0A. It has been

TABLE II.

Displacements of Components II., 1912 *March* 22.

Normal.	Potsdam.		Ottawa.		Mt.W.	Mt.H.	Mean.	Residuals. quad.	Residuals. lin.
3798·1	...	...	...	...	...	−18·1	−18·1	·0	+·3
3835·6	...	...	...	...	...	−18·4	−18·4	−·1	+·2
3889·2	...	...	−18·7	*−18·4*	...	−18·6	−18·5	+·1	+·3
3970·2	−18·8	*−19·1*	−19·4	*−19·1*	...	−18·9	−19·0	+·1	+·2
4101·9	−19·4	*−19·7*	−20·2	*−19·9*	−19·7	−19·7	−19·8	0	+·1
4340·6	−20·5	*−20·8*	−21·5	*−21·2*	−21·1	−21·0	−21·0	+·2	0
4861·5	...	...	−24·6	*−24·3*	−24·5	−24·5	−24·4	·0	−·9
							Sum of squares :	·07	1·08

simpler to accommodate the curve to the observations by this device than to alter the coefficients of (2). The value of the correction securing the best accommodation was of course obtained empirically, and its actual amount is −0·95A; but it is, I think, to be interpreted as follows: a correction of −0·5 due to actual change between the two dates and a small systematic difference, −0·4A, between the two sets of measurements.* The sum of these accounts for the necessity of a correction of about the value of the one adopted. It is now in order to inquire whether the equation which we have thus brought over satisfies the observations as well as that of a straight line passing through the origin. The best straight line of that description is the broken one shown in the sketch. There can be no doubt that the curve affords the better representation. The last two columns of Table II. give the residuals from the curve and straight line respectively. I think that the observations confirm, in so far as confirmation is possible within

* See footnote * on p. 194.

their restricted range, the correctness of the conclusions based on the measures of March 23.

Observations of March 30.—These consist of single-prism photographs of the visible and the ordinary photographic regions, and two of the ultra-violet. Components I. and II. are each double. Referring particularly to Component II., since in I. the lines are too close for easy measurement, we shall designate its members as "*a*" and "*b*," "*a*" being the one of least displacement. These components are clearly resolved only on the plate of the blue and violet region—that is to say, from H_ζ to H_β (3889 to 4861 A),—and here they show displacements very closely proportional to the wave-lengths, though the range is not sufficient to test strictly the validity of the law. Above and below those limits a number of complications develop, which we can hardly take the space to describe, but which militate against the competency of the observations to determine between a law of direct proportionality and one involving a small quadratic term. The observations of March 30 are therefore, for the present, regarded as indeterminate.

General Conclusions.

As already stated in the forecast of conclusions, the measurements recorded in the foregoing paragraphs are taken to indicate that on two consecutive days, where the dark hydrogen lines were most suitable for measurement, there was an appreciable departure from the law of direct proportionality of displacement to wave-length. Whether representation by that law was inexact at other times, when the lines could not be so precisely measured, cannot be stated.

Assuming it to be established that the displacement relations on March 22–23 were as expressed by equation (2), it is apparent that the explanation of the shift of the lines in terms of Doppler's principle is not going to be a simple matter. It is, of course, conceivable that the displacement may be a Doppler effect, modified by something else; but until an independent foundation can be laid for the assumption of the extraneous factor we cannot, I think, accord much favour to that point of view. In any event, the disturbance would probably have to be very considerable, for if we assume it to be represented by the quadratic term, leaving the whole of the first term as an expression of the velocity shift, the term of disturbance at H_α is numerically greater than half the other.

There is a somewhat striking phenomenon shown by the components of the lines II. on a plate of March 30 which is perhaps suggestive of an explanation of the departure from the proportionality law. As we pass from one member of the Balmer series to the one of next greater wave-length, the more refrangible component of II., which we have termed II.*b*, increases in strength with respect to its companion. It is very weak at H_ϵ, increases almost to equality with II.*a* at H_γ, and is the stronger at H_β.

Presumably it would be the dominant line at H_α. The idea suggests itself that in the observations of lines II. on March 23 we may be dealing with unresolved doublets, the components of which behave in just such a manner. Qualitatively the effect would be similar to the one observed, but the hypothesis must be set aside, for, even under assumptions most favourable to it, the H_β and H_γ lines would have to be wider than measurement determines them. But these observations, inasmuch as they show that the relative strength of absorption can vary from one end of the series to the other, suggest that the absorption of the various members may be effected in different regions of the nova, where the gases can be conceived to have different velocities; that is, we may be dealing with a phenomenon analogous in some respects to those observed in different levels of the solar atmosphere.

I do not offer the foregoing explanation as pointing the way to any opinion of my own with respect to the interpretation of line displacements in the spectra of the temporary stars, but merely suggest it as offering a possible basis for the adjustment of a radial velocity hypothesis to the actual data of observation, in case we should be forced by a preponderance of evidence to the adoption of such a hypothesis. Speaking generally, I am disposed to emphasise the view, which informal discussion with other astronomers leads me to believe I am not alone in holding,* namely, that, while the chemical origin of most of the nova radiations is known—a result due largely to the brilliant accomplishments of Sir Norman Lockyer and the group of astrophysicists who were at one time or another associated with him in the study of enhanced spectra,—we are, as yet, hardly on the threshold of an understanding of the real nature of the temporary stars; and that for the present our chief concern must be the collection of facts. With regard to the particular phase of the problem with which this paper deals—the law of displacement of lines,—I do not feel assured that the range of wave-length which has generally been available for its investigation, let us say from 3970 to 4861A, is sufficient to serve as the basis of generalisation with respect to its exact expression. It is rather unfortunate that more observations have not been made of the H_α line, which, as will be seen by a glance at fig. 1, occupies a strategic position at the lower end of the readily observable spectrum. The ultra-violet region is also capable of adding greatly to the range of our observations, especially when our knowledge of the enhanced spectra of the elements will have developed in that direction, for the nova spectra are very rich in ultra-violet light. Another opportunity for the enlargement of our experience is, of course, afforded by the observation of as many novæ as possible. Few problems encountered in astronomical research lend themselves readily to solution on the basis of the study of a single object. When the numerous possibilities of adding to our present knowledge will have been developed, we shall perhaps have available a broader basis of fact on which to stabilise our speculations

* See also Plaskett, *Publ. Dom. Obs.*, 1, 168, 1913.

respecting the nature of these fascinating and mysterious bodies. My own mind is open on essentially all the problems which they present, and while velocity may eventually be accepted as accounting for the remarkable phenomena which we observe in their spectra, I cannot agree that the evidence in favour of such an interpretation is, at present, decisive.

Mount Hamilton, California:
1920 *November* 5.

Note on Mr. Wright's Paper on the Displacements of the Hydrogen Absorption Lines in the Spectrum of Nova Geminorum, 1912. By F. J. M. Stratton, D.S.O., M.A.

Mr. Wright criticises a statement in a recent note of the writer's (*M.N.*, *R.A.S.*, **80**, 542) that the evidence from the spectrum of Nova Geminorum II. is *decisive* in favour of the Doppler effect as the proper interpretation of the displacement of the absorption lines. He bases his argument on the behaviour of the hydrogen absorption lines. This is, I think, unfortunate, as these lines are parts of very complex bands containing several bright maxima as well as the absorption components. The exact portion of the band which is taken as the absorption line depends in part on the exposure of the plate, and may vary for purely photographic reasons from line to line; *e.g.* irradiation from the very bright emission band of H_α would tend to displace the measured $\delta\lambda$ of the accompanying absorption towards the violet. Further, for the hydrogen series beyond H_η the absorption components of one line are superimposed on neighbouring radiation bands of hydrogen; the position of the measured absorption lines may be affected by this, especially as the maxima and the absorption lines are not as a rule symmetrical in intensity about their centres. We may get an absorption line from one source coinciding with a bright maximum from another; *e.g.* H_κ absorption II.* at $\lambda 3741{\cdot}0$ coincides with maximum II. from H_λ. The sources of these two parts of the spectra are probably separate in the nova. We may have a superposition of bright and dark effects in the spectrum as distinct from the ordinary effects of absorption against a continuous background.

The above suggestion that the material on which Mr. Wright's criticism is based is not homogeneous can be tested. The following table shows that Mr. Wright's measures of displacements on 1912 March 23 agree very fairly with those of two Allegheny plates on 1912 March 22 and 25 measured by the writer.

* I have used the notation adopted in my complete paper published in the *Annals of the Solar Physics Observatory*, **4**, part 1.

TABLE I.

Displacements to the Violet of Hydrogen Absorption Lines.

	Component II.			Component III.		
	March 22.	23 (Wright).	25.	22.	23 (Wright).	25.
	λ.	λ.	λ.	λ.	λ.	λ.
H_λ	10·2	9·5	9·7	17·0	17·2	17·5
H_κ	10·2	10·3	9·2	17·5	16·7	17·7
H_ι	10·1	9·6	10·2	17·7	...	18·2
$H\theta$	10·3	10·2	10·1	18·1	16·9	17·8
H_η	10·9	10·6	9·9	18·4	17·5	18·4
$H\zeta$	10·8	10·8	10·6	19·2	17·6	18·7
H_ϵ	11·6	11·7	(12·0)*	19·1	18·5	19·3
$H\delta$	12·0	11·0	11·1	19·9	18·9	19·7
H_γ	12·6	12·4	11·6	21·1	20·1	20·8
$H\beta$	14·2	13·8	13·0	24·6	23·6	22·7

But though the Allegheny and Lick plates agree with one another, there are serious internal differences on the Allegheny plates which reveal a lack of homogeneity between the hydrogen lines on one plate.

TABLE II.

Widths of Absorption Lines.

	Component II.		Component III.	
	March 22.	25.	22.	25.
	λ.	λ.	λ.	λ.
H_λ	2·29	2·27	2·99	1·89
H_κ	2·41	1·55	2·38	2·82
H_ι	1·40	1·37	2·66	2·84
$H\theta$	2·06	1·03	1·86	2·67
H_η	2·35	2·65	3·12	3·31
$H\zeta$	1·97	1·29	3·45	3·60
H_ϵ	3·00	3·50	3·27	4·17
$H\delta$	3·08	1·56	3·87	4·56
H_γ	3·43	4·76	4·48	4·00
$H\beta$	...	5·14	5·14	4·27

There is a connection between the widths of the absorption lines and the amount of their displacement. For each date the lines whose displacement factors $10^4\delta\lambda/\lambda$ are largest have been grouped together and the mean values of $10^4\delta\lambda/\lambda$ and of

* Affected by Ca 3968, as shown by the abnormal displacement and width (see Table II.).

$(10^4 \times \text{width})/\lambda$ determined. These with the corresponding figures for the less displaced lines are given in Table III.

TABLE III.

	Component II.		Component III.	
	$10^4\delta\lambda/\lambda$.	$(10^4 \times \text{Width})/\lambda$.	$10^4\delta\lambda/\lambda$.	$(10^4 \times \text{Width})/\lambda$.
March 22	28	7·2	50	9·7
	27	5·3	47	6·9
March 25	27	5·0*	48	9·1
	26	5·7	46	7·1

In general it is clear that absorption lines which are relatively broader are more displaced; presumably they have widened on the ultra-violet side. The lines chiefly affected are those of low-term numbers in the Balmer series.

What is the bearing of these results on the alternative expressions for the displacement? Mr. Wright favours the form $\delta\lambda = A\lambda + B\lambda^2$, while the writer prefers the form $\delta\lambda = A'\lambda$. Alternative solutions have been worked out for both absorption components on March 22 and 25. The method of least squares was used and the lines H_ι, H_ϵ were omitted as probably affected by other lines. The solutions are as follows:—

TABLE IV.

Alternative Solutions.

	March 22.	23.	25.	
Component II.				
A	−21	−24	−23	quadratic solution
B	−17	− 7	− 8	quadratic solution
$[\Sigma vv$	0·46	0·13	0·57]	quadratic solution
or				
A′	−28	−27	−26	linear solution.
$[\Sigma vv$	1·01	0·18	0·85]	linear solution.
Component III.				
A	−36	−34	−49	quadratic solution.
B	−30	−30	+ 4	quadratic solution.
Σvv	0·99	0·85	0·39	quadratic solution.
or				
A′	−48	−46	−47	linear solution.
$[\Sigma vv$	2·85	3·47	0·44]	linear solution.

The change in value for B, with its consequent changes in A, for component III. is the most striking feature in the table above.

* A glance at Table II. shows that for component II. the material on March 25 was unusually heterogeneous. Some other disturbing factor was present.

A′, on the other hand, is very stable in value. The sum of the squares of the residuals is necessarily less in the solution involving two unknown constants, but the difference is not striking. From the steadiness of A′ one would be inclined to regard the linear solution as the one which corresponds to a physical reality. This view is supported by the figures for other elements on the same dates.

TABLE V.

	March 22.	23.	24.
Component II.			
A′	−28(pTi, pFe, pCa, pCr, He)	−26(pTi, pFe)	−27(pFe, pTi, He)
		−29(pCa)	−29(pCa)
Component III.			
A′	−44(N, O, He)	−45(N)	−48(He, pC, pFe, pCa)
			−49(N)

There are minor differences between the various elements, but there is a good general agreement, suggesting that for each element the displacement varies with the wave-length and that the displacement factor is the same or nearly so for several elements. The Doppler effect is the only known physical effect that fits the observed phenomena.

It must be at once admitted that on March 22, 23—but not on March 25—a modification of the Doppler effect was present. The absorption lines at the red end of the Balmer series were broadened towards the violet. This must be coupled with the fact that these separate hydrogen absorptions are themselves sometimes divided by a narrow bright centre. The outstanding anomalies to which Mr. Wright's paper draws attention may be of great value as a further clue. They may indicate the nature of the temperature and pressure gradients in the atmosphere of the nova. They do not affect the writer's general belief in the Doppler effect as being in large part the explanation of the displacements of absorption lines in the early stages of nova spectra. This belief has been greatly strengthened by the recent work of Mr. Wright's colleagues at the Lick Observatory on Nova Aquilæ III.

Perhaps the writer may add that though the accumulating evidence has compelled him to adopt a definite view on this point, he welcomes the more open point of view of Mr. Wright.

Note on the Monoceros Stream recently discovered by Axel Corlin.
By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. In *A.J.*, 782, an able and very interesting discussion is given by Mr Axel Corlin of Upsala of a new cluster the members of which are moving in the direction of *β Monocerotis*. The author has given the co-ordinates (R.A. Dec.) and spectroscopic parallax of eight "safe" stars, and of a score of others perhaps belonging to the cluster; but possibly he has not noticed its general *flatness*. The flatness of the Ursa Major cluster was pointed out some time ago, and this seems to be possibly a similar case.

2. Taking first Corlin's Table I., in which there are 12 stars, it is easy to form the co-ordinates

$$X = R \cos\alpha \cos\delta, \quad Y = R \sin\alpha \cos\delta, \quad Z = \sin\delta,$$

where R is the distance expressed in parsecs; and it is seen at a glance that the co-ordinate Z does not vary as much as the others.* If we arrange the stars in order of Z, as is done in Table I., we also see that a rotation of 15° round the Y axis will diminish the range in Z. The rotation $\zeta = Z\cos 15° - X \sin 15°$ is given in the last column, preceded by the complementary $\xi = X \cos 15° + Z \sin 15°$.

TABLE I.

No.	Adams and Joy.	α.	δ.	R.	X.	Y.	Z.	ξ.	ζ.
		°	°						
4	247	199	+44	33·3	−22·7	− 7·8	+23·2	−16·2	+28·2
2	36	32	+67	22·7	+ 7·5	+ 4·7	+20 9	+12·5	+18·4
12	484	349	+28	21·7	+18·8	− 3·7	+10·1	+20·7	+ 5·1
1	24	21	+21	18·2	+15·9	+ 6·1	+ 6·5	+17·0	+ 2·3
10	477	347	+57	6·3	+ 3·3	− 0·8	+ 5·3	+ 4·6	+ 4·3
7	313	240	+11	16·7	− 8·2	−14·2	+ 3·2	− 7·1	+ 5·1
5	254	206	+ 7	20·8	−18·6	− 9·0	+ 2·5	−17·5	+ 7·1
11	483	348	+ 5	20·8	+20·3	− 4·3	+ 1·8	+20·0	− 3·4
3	180	154	− 1	15·9	−14·3	+ 7·0	− 0·3	−14·0	+ 3·3
8	337	252	− 8	5·7	− 1·8	− 5·4	− 0·8	− 1·9	− 0·4
9	475	346	− 3	20·8	+20·2	− 5·0	− 1·1	+19·2	− 6·2
6	271	222	−24	16·7	−11·3	−10·2	− 6·8	−12·6	− 3·8

3. The values of ζ are all small except for the stars 2 and 4, which are two of the eight regarded as "safe" by Corlin. On the other hand, he remarked that stars 5 and 8 "do not show any resemblance to the cluster-stars or to each other," being of spectral types F9 and Md, whereas the other ten are all K stars. As far as ζ is concerned, stars 5 and 8 fit in well.

4. The direction cosines of the normal to the adopted plane, to which there is a rough parallelism, are thus −0·25, 0·00, +0·97,

* The stars 4, 2, 6 are excluded in making this statement.

and taking those of the Galaxy as $-0\cdot87$, $-0\cdot18$, $+0\cdot45$, the angle between them is 48°. The direction cosines of the true motion $94^{\circ}\cdot5-4^{\circ}\cdot5$ are $-\cdot08$, $+1\cdot00$, $-\cdot08$, which thus makes an angle 93° with the normal to cluster; in other words, the cluster is travelling nearly in the plane to which it is parallel; and this was found to be the case for the Ursa Major cluster (*Obs.*, 1911 June, p. 246).

5. Corlin proceeds to give a list of 25 stars which *may* belong to the stream having proper motions in the right direction within 6°. For these stars the parallax was computed from the proper motion on the assumption that they belong to the stream and have its adopted velocity of 62 km. The co-ordinates of these were plotted to see whether ζ was small for any large number of them, but no arrangement of this kind was perceptible. The eye was caught, however, by a sort of lane running through the stars in a direction which suggested the formation of the co-ordinate

$$Z_1 = 0\cdot316(3Z + X),$$

and the consideration of stars which seemed to lie in planes perpendicular to this direction suggested also the co-ordinates

$$Y_1 = 0\cdot169(3X + 5Y - Z)$$
$$X_1 = 0\cdot267(-3X + 2Y + Z).$$

It will be seen that (X_1, Y_1, Z_1) form a rectangular system. These co-ordinates are given in Tables II. and III. The stars have been rearranged in order of Z_1 to bring out the feature which suggested it, viz. the gap between $Z_1 = -3\cdot1$ and $-10\cdot4$, and for convenience of treatment they have been divided into separate tables at this gap, but the first five columns in Tables II. and III. are continuous.

Table II.

No.	Abs. Mag.	X_1.	Y_1.	Z_1.	C_1.	$Z_1 - C_1$.	Y_2.	X_2.	Z_2.
3	6·1	+ 0·3	+11·4	+30·2	+30·2	·0	− 5·6	−21·0	+31·7
8	6·0	+42·8	− 7·0	+24·9	+25·1	·2	−11·2	+43·3	+22·2
6	6·0	+39·4	+ 1·7	+22·4	+22·6	·2	− 3·2	+38·3	+24·1
25	7·3	− 9·1	+ 5·2	+22·0	+22·6	·6	− 8·3	− 9·9	+20·7
4	6·7	+ 5·5	+ 1·6	+20·0	+20·0	·0	− 7·9	+ 5·1	+18·7
19	7·1	+ 0·4	− 4·6	+17·9	+17·4	+ ·5	−12·8	+ 1·3	+13·1
10	7·5	+31·5	−18·5	+16·2	+17·4	−1·2	−18·5	+34·5	+ 7·9
2	7·7	− 8·9	+13·0	+11·1	+ 9·8	+1·3	+ 3·8	−11·3	+15·1
7	5·8	+20·2	+ 0·6	+10·0	+ 9·8	+ ·2	− 1·2	+19·7	+11·0
5	7·6	+ 3·6	+15·7	+ 9·2	+ 9·8	− ·6	+ 9·2	+ 0·5	+16·1
24	7·6	− 2·5	+ 0·7	+ 7·4	+ 7·2	+ ·2	− 3·5	− 2·5	+ 6·5
23	7·8	−20·3	+ 3·4	+ 7·0	+ 7·2	− ·2	− 4·1	−20·6	+ 5·7
22	6·9	−20·8	− 4·0	+ 5·0	+ 4·6	+ ·4	− 9·5	−19·6	+ 0·2
15	7·9	+ 9·1	−19·5	+ 3·4	+ 4·6	−1·2	−16·6	+12·7	− 5·9
16	7·9	+ 4·2	−12·2	+ 2·2	+ 2·1	+ ·1	−10·7	+ 6·5	− 3·7
20	7·1	−20·5	− 4·9	− 3·1	− 3·1	·0	− 6·0	−19·1	− 7·1

TABLE III.

No.	Abs. Mag.	X_1.	Y_1.	Z_1	C_1.	$Z_1 - C_1$.	y.	z.
12	6·6	+14·4	−16·0	−10·4	−10·4	0·0	− 0·2	−19·0
1	7·1	−15·0	+14·5	−13·8	−12·8	−1·0	+19·5	+ 4·3
21	6·0	−13·1	+ 1·1	−13·9	−12·8	−1·1	+12·2	− 6·8
18	6·4	−13·3	−11·1	−14·7	−15·2	+ ·5	+ 6·0	−17·3
17	7·2	−12·0	−13·4	−14·9	−15·2	+ ·3	+ 5·0	−19·4
11	6·5	+ 7·5	− 7·7	−15·5	−15·2	− ·3	+ 8·6	−15·0
13	6·2	+11·5	−13·7	−17·6	−17·6	·0	+ 7·0	−21·1
9	6·3	+29·2	− 1·9	−22·7	−22·4	− ·3	+17·8	−14·1
14	6·1	+ 1·3	− 6·6	−24·7	−24·8	+ ·1	+16·9	−19·2

Now, in dealing with these figures attention was drawn to the fact that the intervals between co-ordinates seemed to be multiples of a unit interval. In Tables II. and III. this hypothesis is exhibited for Z_1 under the heading C_1, and the differences shown under heading $Z_1 - C_1$ are all small except in five cases, viz. stars 10, 2, and 15 in Table II., and stars 1 and 21 in Table III. It may not be easy to justify this hypothesis physically, although we are familiar with the appearance of a nebulous arm breaking up into drops; but it is interesting to adopt the hypothesis as a purely empirical one, and to see where it leads.

Firstly, it leads us to separate the two groups Tables II. and III. The formulæ are for Table II. $\pm 2{\cdot}56\,n - 0{\cdot}50$; for Table III. $\pm 2{\cdot}40\,n - 0{\cdot}80$.

The coefficients of n are similar, but any attempt to combine them would spoil the accordance. If we extend either formula into the other table, we find that it does not suit.

Secondly, let us first consider Table III. The hypothesis would necessitate our omitting stars 1 and 21 from this group. Now we see that these two stars are also discordant in Y_1. If we omit them the range in Y_1 is small, and can be reduced by a combination with Z_1.

In the last two columns are given

$$y = 0{\cdot}277(2Y_1 - 3Z_1)$$

and

$$z = 0{\cdot}277(3Y_1 + 2Z_1),$$

and it is seen that this rotation of axes makes z very nearly constant except for these two stars. Omitting them, the range in z is only 7·0 parsecs, while that in X_1 is 42 parsecs, and in y is 18. We thus get a very flat cluster well separated from the other stars.

Since $$z = +{\cdot}595X + {\cdot}700Y + {\cdot}385Z,$$

the angle made by z with the direction of motion is 52°, and with the Galaxy is (118° or) 62°.

The unit interval has now shrunk to one parsec in both y and z. The formulæ $y = +10{\cdot}8 \pm 1{\cdot}0\,n$ and $z = -19{\cdot}15 \pm 1{\cdot}0\,n$ fit the

observations very closely; but the smallness of the interval makes the significance more doubtful. For X_1 the formula $+2{\cdot}1 \pm 3{\cdot}0\,n$ gives good results for all the stars except 1 and 17. If we exclude 17 for this reason as well as 1 and 21, we may notice the close range of the remaining stars in magnitude (6·6 to 6·1).

Returning now to Table II., it was seen by inspection that the range of a co-ordinate

$$Y_2 = 0{\cdot}845(Y_1 - 0{\cdot}6Z_1 + 0{\cdot}2X_1)$$

would be small, except for a few stars, viz. Nos. 10, 2, 5, and 15. Of these the column $Z_1 - C_1$ has already suggested the omission of 10, 2, and 15, and the difference $-{\cdot}6$ for No. 5 is one of the largest remaining. If we omit all four stars, the range of Y_2 is then from $-1{\cdot}2$ to $-12{\cdot}8$.

Y_2 is no longer perpendicular to X_1, but we can form

$$X_2 = 0{\cdot}980(X_1 - 0{\cdot}2Y_1)$$

and

$$Z_2 = 0{\cdot}830(1{\cdot}04Z_1 + 0{\cdot}12X_1 + 0{\cdot}60Y_1),$$

and we see then that the range in X_2 is from $+43$ to -20, and in Z_2 is from $+32$ to -7, so that the Y_2 dimension is comparatively small.

If we now test X_2 for equal intervals, we find that the formula

$$+0{\cdot}9 \pm 5{\cdot}3\,n$$

fits all stars except 10, 2, 7, and 24. And as regards Z_2, the formula

$$-0{\cdot}8 \pm 2{\cdot}85\,n$$

suits all the stars but 3, 25, 2, 24, 22. These exceptions are rather numerous, and it seems possible that we have not selected the right axes; there is nothing much to help us here, but it will be seen that X_2 must be near the longest dimension, since the rotation from X_1 leaves it practically unaltered in range.

If we may accept Y_2 as the normal to the plane of another long, flat cluster, since

$$Y_2 = +{\cdot}133X + {\cdot}804Y - {\cdot}579Z,$$

the inclination of Y_2 to the direction of motion is 43°.

Thus the assumed short axis is not very near perpendicularity to the direction of motion either for Table II. or Table III.

Summary.

1. The 12 stars of Axel Corlin's Table I. (*A.J.*, 782) form, with two exceptions, a flat cluster travelling nearly in its plane (inclination of direction to plane 6°).

2. The 25 stars of his Table III. can be divided into two flat clusters, but the inclinations of the direction to the planes are 38° and 47°, not very small.

3. There is some evidence of a rhythmic arrangement of the stars, which makes their co-ordinates multiples of some unit interval.

[*Note added Jan.* 29.—On reading the proof it was felt that perhaps the best condition to look for was that the short axis should be perpendicular to the direction of motion. Making trial, the co-ordinate $Z_1 - 0{\cdot}3Y_1$ divides Table II. into two well-separated groups (omitting only star 20), and the inclination to the motion is now 70°. The co-ordinate $Z_1 + 0{\cdot}2X_1$ gives for Table III. a very flat cluster, except for stars 12 and 14, and the inclination is sensibly 90°. It was also noticed that the range in ζ in Table I. would have been further reduced if the rotation round the axis of y had been taken as 11° instead of 15°.]

Note on Changes in the Period and Light-curve of the Cluster Variable SW Andromedæ. By Harlow Shapley.

1. Non-uniformity of period, similar to that of the star Bailey No. 33 in Messier 5 discussed by Professor Turner in *Monthly Notices*, 1920 May, p. 640, appears also to be a property of the isolated cluster variable SW Andromedæ for which observations and light elements are published by Martin and Plummer in *Monthly Notices*, 1919 Dec., p. 212. The elements given by Martin and Plummer,

$$\text{Max.} = \text{J.D. } 2422\ 227{\cdot}411 + 0{\cdot}441848\ \text{E},$$

are based upon a series of observations extending over three months in 1919 and an earlier epoch of maximum. The almost identical provisional period by Seares,*

$$\text{Max.} = \text{J.D. } 2418\ 132{\cdot}805 + 0{\cdot}44185\ \text{E},$$

is based upon observations on six nights by Seares and Haynes in 1908 July. Both of these periods fit their respective series of observations extremely well; but apparently other values would also represent the observed maxima within the irregularities now found to exist (cf. section 6, and fig. 1).

2. In 1908 August observations † by Haynes showed that the published period was incorrect in the fourth decimal place (or had changed); and my observations † at the Laws Observatory fourteen months later indicated that the maxima were probably falling one whole period later than the predicted times. My observations at Princeton in 1913–14 gave maxima deviating from two to five hours from the times predicted by Seares' provisional elements, and they also showed an oscillation in the time of rise from minimum to maximum light.‡

* *Laws Observatory Bulletin*, No. 16, 1908 Aug. 3.
† Unpublished. See Table II. below.
‡ *Publications of the American Astronomical Society*, 3, 16, 1914.

In view of the importance, for considerations of the sources of stellar radiation, of changes in the periods and light-curves of cluster and Cepheid variables, the available data on SW Andromedæ are briefly presented below, although they do not approach in completeness or homogeneity the material derived by Barnard * for the variable Bailey No. 33 in Messier 5.

3. Table I. contains the Princeton observations, made with a polarising photometer attached to the 23-inch refractor. B.D. + 28°53 was used as comparison star; its photographic magnitude is 10·42 according to Martin and Plummer.

TABLE I.

Princeton Observations of SW Andromedæ.

Date.	J.D., G.H.M.T.	$v-a$.	Date.	J.D., G.H.M.T.	$v-a$.	Date.	J.D., G.H.M.T.	$v-a$.
1913	2420000+		1913	2420000+		1913	2420000+	
Oct. 31	072·468	+0·90	Nov. 4	076·580	+0·27	Dec. 5	107·559	+0·12
	·476	0·82		·587	0·26		·570	0·08
	·483	0·98		·594	0·00			
	·491	0·87		·601	0·01	Dec. 13	115·486	0·71
	·504	0·90		·616	−0·16		·494	0·45
	·512	0·97		·625	+0·04		·502	0·28
	·522	0·96					·512	0·12
	·535	1·01	Nov. 6	078·458	0·29		·520	0·06
	·542	0·94		·466	0·42		·528	0·04
	·550	1·04		·472	0·42		·536	0·12
				·480	0·49		·542	0·06
Nov. 1	073·527	0·13		·487	0·50			
	·534	0·09		·530	0·65	1914		
	·542	0·26		·538	0·68	Feb. 9	173·469	0·15
	·550	0·33					·477	−0·04
	·557	0·14	Nov. 11	083·453	0·69		·523	+0·28
	·569	0·17		·462	0·71		·537	0·28
	·576	0·32		·471	0·81			
	·582	0·35				Feb. 12	176·530	0·54
	·590	0·29	Nov. 24	096·446	1·02		·548	0·25
	·596	0·48		·459	0·75			
	·622	0·47		·471	0·56	Feb. 16	180·520	0·19
				·478	0·39		·528	0·03
Nov. 4	076·530	0·92		·528	0·01		·538	−0·13
	·537	0·97					·549	+0·03
	·544	0·87	Dec. 5	107·524	0·72			
	·552	0·86		·532	0·51	Feb. 24	188·482	0·25
	·562	0·69		·540	0·40		·492	−0·09
	·570	0·48		·550	0·21		·502	+0·01

* *Publications of the American Astronomical Society*, 4, 76, 1919.

Table II. contains a list of all maxima clearly deducible from the observations. In general they are not accurately determined beyond the second decimal place. The first six maxima were published by Seares (*loc. cit.*). All times are heliocentric, and reduced to Greenwich. The four times of maximum given without observational detail by Yendell in *Astronomical Journal*, 29, 99, 1916, are not used, for though contemporary with the Princeton work they disagree widely; in fact, they agree excellently with the predicted times from Seares' provisional elements which were then used in Hartwig's ephemeris for the prediction of maxima.

The residuals in Table II., $O-C_1$ and $O-C_2$, in thousandths of a day, are computed from elements (1) and (2) below; the letters in the fourth column designate the observers, Haynes, Seares, Shapley, and Martin and Plummer.

TABLE II.

Observed Maxima of SW Andromedæ.

Observed Maximum.	Wt.	$O-C_1$.	$O-C_2$.	Obs.	Observed Maximum.	Wt.	$O-C_1$.	$O-C_2$.	Obs.
2418132·802	3	− 6	+ 8	H	2420076·612	4	−19	−13	Sh
133·685	1	− 7	+ 7	H	096·513	2	−16	−10	Sh
147·828	4	− 14	0	S & H	107·577	2	− 7	− 1	Sh
148·703	3	− 23	− 9	S & H	115·530	3	−13	− 7	Sh
150·921	3	− 16	− 2	H	173·477	3	+ 8	+14	Sh
151·810	2	− 11	+ 2	S & H	180·537	4	− 7	− 1	Sh
171·726	2	+ 7	+ 20	H	188·500	2	− 3	+ 3	Sh
175·681	3	− 18	− 5	H	2227·412	2	+17	+15	M & P
586·585	2	+101	+113	Sh	2258·347	4	− 1	− 3	M & P
617·528	2	+·91	+103	Sh					

4. For the derivation of a mean period, the observations are grouped by twos and threes in Table III. A least squares solution gives the following heliocentric elements and probable errors:

$$\text{Max.} = \text{J.D. } 2420076{\cdot}631(\pm 0{\cdot}008) + 0{\cdot}4421801\,E(\pm 0{\cdot}0000024) \qquad (1)$$

The residuals $O-C_1$ in Tables II. and III. are unsatisfactory. Omitting the 1909 observations from the solution, we derive:

$$\text{Max.} = \text{J.D. } 2420076{\cdot}625(\pm 0{\cdot}002) + 0{\cdot}4421818\,E(\pm 0{\cdot}0000005) \qquad (2)$$

TABLE III.

Mean Maxima used in Solution.

Date.	Maximum.	Wt.	E.	$O-C_1$.	$O-C_2$.
1908 July 10	2418133·686	4	−4394	− 5	+ 8
25	148·708	7	−4360	−18	− 4
28	151·807	5	−4353	−14	− 1
Aug. 21	175·691	5	−4299	− 8	+ 5
1909 Nov. 6	617·533	4	−3300	+96	(+108)
1913 Nov. 4	2420076·613	6	0	−18	− 12
Dec. 13	115·533	5	+ 88	−10	− 4
1914 Feb. 16	180·543	9	+ 235	− 1	+ 5
1919 Oct. 26	2422258·353	6	+4864	+ 5	+ 3

5. Although the period differs in the fourth decimal place from the values given by Seares, and by Martin and Plummer, the elements (2) represent all the maxima, except two, with an average deviation of less than ten minutes, and are probably the best for future prediction. A uniform mean period might be

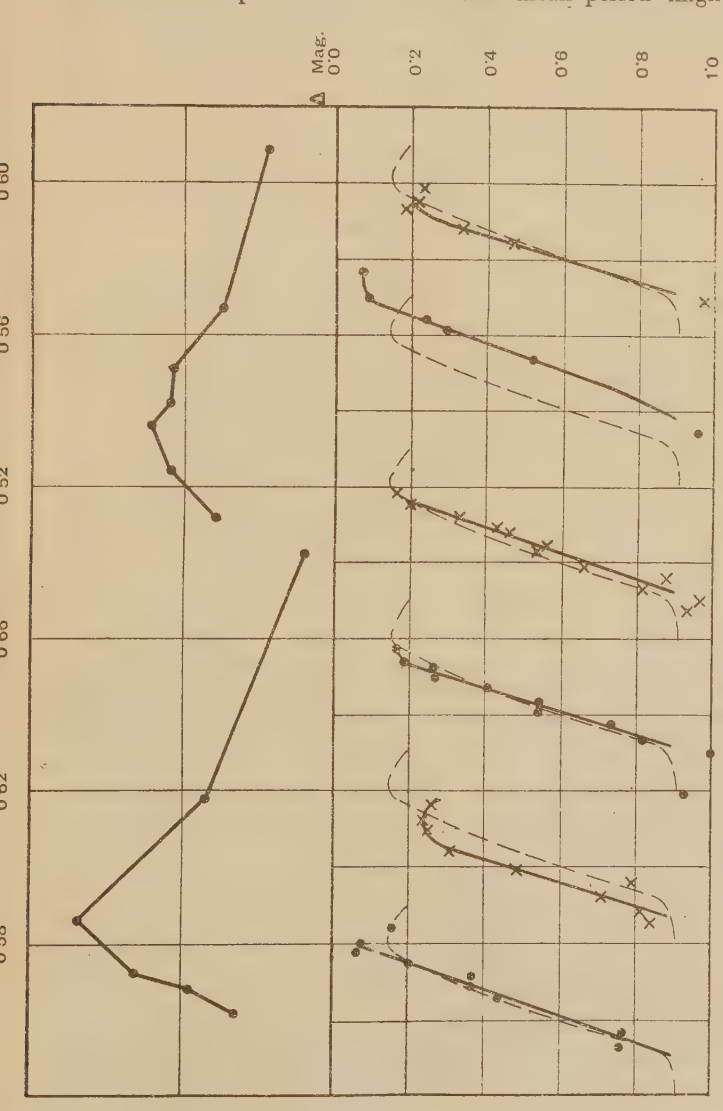

Fig. 1.—Visual observations of SW Andromedæ. *Above:* Maxima of 1909 Oct. 6 and Nov. 6, by Shapley. *Below:* Ascending branch of the maxima of 1908 July 24, 25, 27, 28, Aug. 17, 21 (in order), by Seares and Haynes. The broken line is the mean curve.

adopted except for the observations made in 1909, but there appears to be no reason to doubt their testimony of a change. They are given in Table IV., and plotted in the upper part of fig. 1 as an illustration of diversity in shape of maxima a month apart. Better illustrations of the variations in shape of the maxima of such stars are given in *Mount Wilson Contributions*, Nos. 104 and 112, for XX Cygni and RR Lyræ.

TABLE IV.

Observations of SW Andromedæ in 1909.

Date.	Time.	Δ_m
	d	
Oct. 6	2418586·561	0·54
	·568	0·42
	·572	0·28
	·586	0·12
	·618	0·46
	·682	0·72
Nov. 6	2418617·512	0·48
	·524	0·36
	·536	0·31
	·542	0·36
	·551	0·37
	·567	0·50
	·609	0·62
	·741	0·56

6. But, in addition to the slow change of period found above, there appears to be good evidence of a short-period or irregular oscillation in the time of maximum. This irregularity is best shown, however, not in the maximum light itself, but in the more accurately measured rise to maximum light. To illustrate the peculiarity, to which I have frequently called attention for other cluster variables,* the individual observations by Seares and Haynes, which have been placed at my disposal, are plotted for the rising branch of the curve in the lower part of fig. 1 for six maxima (third to eighth, inclusive, of Table II.).

The deviations from the mean curve (broken line) considerably exceed the possible systematic errors. Obviously a strictly uniform period cannot satisfy the observations, even over an interval of less than four weeks.

7. A similar oscillation in the time of rise to maximum light has been found and illustrated for the cluster variable RR Lyræ.† Its period also has a slow variation in a cycle of possibly sixteen

* *Mount Wilson Contrib.*, No. 92, 1914; 104, 1915; 112, 1916; 159, 1918.

† *Publications of the American Astronomical Society*, 3, 16, 1914; *Mount Wilson Contrib.*, No. 112, fig. 4, 1916.

years. If in these stars the cycle of the slow variation is proportional to the period itself, then the indication of a secular decrease in the period of δ Cephei, discussed by Eddington * and Hertzsprung, † may be only one phase of a cyclic phenomenon with a period of one or two centuries, rather than a suggestion of the measurable decay of Cepheid variation.

Mount Wilson Observatory:
1920 *September.*

Note on the Cluster N.G.C. 6633. By W. J. Luyten.

(*Communicated by the Astronomer Royal.*)

During the summer of 1920 a few plates were taken of the star cluster *N.G.C.* 6633 for the purpose of measuring the positions of its stars, and, by comparing with older measures, deriving proper motions in the cluster itself, if possible.

Four plates were obtained, each with three exposures of about two minutes on Ilford Empress plates. In the case of two of the plates a diffraction grating was placed in front of the objective in order to get rid of a magnitude equation in the measures. A réseau was printed on the plates in the usual way, and they were measured in the Greenwich astrographic micrometer.

One plate was chosen as standard and the others reduced to it by means of linear corrections $ax+by+c$ and $dx+cy+f$. All the plates having been obtained on or near the meridian, and the corrections for second order terms of refraction and aberration therefore being very small (well under 0″·01), no correction for these has been applied. For this reduction all the stars measured on each plate were used, and the mean of the final values taken; from the deviations of this mean the mean error was computed, and found to be equal to 0″·030 in R.A. and 0″·032 in Dec.

The final values thus obtained are tabulated below; the first two columns give the number and magnitude according to Valentiner (*Beob.*, Mannheim, iii.); the third and seventh columns the X and Y in réseau intervals of the 26-inch refractor, one unit roughly corresponding to 151″.

To see whether there is any proper motion in the cluster itself, these results were compared with Nijland's measures on photographic plates (*Inaug. Dissert.*, Utrecht). To his co-ordinates (pp. 95–96) were applied his corrections for refraction, and the results converted into rectangular co-ordinates on the 26-inch scale. The X and Y thus obtained were corrected for difference in scale (it was tacitly assumed that the cluster had not sensibly altered its distance from us in the time between the two observations), orientation, and zero-point, the values of the six constants

* *Observatory*, 42, 338, 1919.
† *Astronomische Nachrichten*, 210, 17, 1919.

a, *b*, *c*, *d*, *e*, *f* being derived from all Nijland's stars. The residuals that were still left, and the sum of which should be equal to zero according to the method of reduction, must show the motion, if any, of the cluster stars *inter se*, and are given in cols. 4 and 8. These small values can be wholly explained by errors of measurement, for the mean error of the results is ″·07 and ″·11 in R.A. and Dec. respectively (Nijland's m.e. being ″·06 and ″·11 respectively), and proper motions can therefore not be deduced from these data alone. A comparison was accordingly made with the results of Valentiner and Kruse (*Veröff.*, Heidelb., Bd. vii., No. 3), so in cols. 5 and 9 are inserted the differences Nijland–Valentiner as given by the latter (*l.c.*, p. 75), and in cols. 6 and 10 the differences Kruse–Valentiner (*l.c.*, pp. 86–87). As, however, both Valentiner and Kruse measured visually with a small telescope of only 2·6 m. focal length, naturally their results are less accurate. This is also shown by their mean error being considerably larger than the others, viz. ″·36 and ″·23 for V., and ″·30 and ″·25 for K. The method of reduction adopted by both Nijland and Kruse is not so differential as the one described above; therefore, also, the residuals will be larger and their sum need not be equal to zero.

As there is no real confirmation between the four observers for any of the stars, the only thing we can say is that, within the area common to all observers, there is no star with sensible proper motion.

If we now assume that there is no motion at all in the cluster, we may treat the proper motions of the individual stars as different measures of the proper motion of the whole. Kruse (*l.c.*, p. 83) has compared meridian observations of the cluster stars, and derived proper motions from the most trustworthy amongst them. If we only use the first five in his table (for the others are not included in the above statement), we find for the weighted mean $+^{s}\cdot019 \pm^{s}\cdot011$ and $-″\cdot12 \pm ″\cdot04$ per century, or $″\cdot31 \pm ″\cdot17$ towards $293° \pm 4°$.

I am greatly indebted to the Astronomer Royal for his permission to use the 26-inch refractor for this purpose, and also for the interest he took in the work.

Val. No.	Mag.	X.	L.–N. 25.	N.–V. 17.	K.–V. 34.	Y.	L.–N. 25.	N.–V. 17.	K.–V. 34.
	m		″	″	″		″	″	″
7	9·5	8·3846	+·18	−·55	−·03	12·6339	+·16	−·28	−·84
18	9·9	8·7814	+ 9	− 117	− 61	15·2248	+ 4	− 40	− 38
26	10·6	9·1156	...	...	− 8	11·7420	...	...	− 49
16	10·0	9·2458	+ 12	− 64	− 47	14·9830	+ 3	+ 81	+ 121
27	10·6	9·2559	...	...	+ 40	11·8545	...	...	− 27
15	10·0	9·3809	+ 8	− 25	− 55	15·5393	0	− 46	− 11
17	10·0	9·4307	+ 3	− 136	− 90	14·7511	+ 15	+ 5	+ 13
11	8·6	9·4334	− 27	+ 43	− 30	15·2076	− 12	− 21	− 17
14	9·0	9·8463	− 3	+ 24	+ 15	15·5566	− 2	− 26	− 4
28	9·8	10·5077	− 10	− 97	+ 9	12·3015	+ 6	− 22	− 53
28	9·8	10·6924	− 6	− 145	+ 65	10·9631	− 6	− 39	− 72
5	8·8	11·2860	− 9	− 37	+ 50	11·8758	+ 6	+ 20	− 12

Val. No.	Mag.	X.	L.–N. 25.	N.–V. 17.	K.–V. 34.	Y.	L.–N. 25.	N.–V. 17.	K.–V. 34.
	m		″	″	″		″	″	″
1	8·4	11·2995	−·18	−·10	+·51	12·7289	−·9	−·10	−·35
9	8·6	11·4314	− 8	0	+ 21	14·1861	+ 3	00	+ 25
29	9·7	11·4972	+ 3	− 146	− 33	10·9570	− 22	0	− 70
30	10·4	11·5561	...	...	+ 66	13·7483	...	...	− 58
2	9·2	12·0429	0	− 97	+ 9	12·5798	+ 8	− 5	− 32
3	9 0	12·2013	− 2	− 46	+ 71	12·4320	+ 9	+ 18	+ 4
4	9·1	12·3571	+ 6	− 42	+ 88	12·9178	− 6	− 23	− 36
13	8·6	12·5267	+ 12	+ 69	+ 42	15·4380	− 6	− 24	+ 48
23	10·2	13·3140	...	...	− 39	12 6603	...	...	− 39
35	10·0	13·3234	..	...	+ 50	16·3706	...	...	− 57
10	9·3	13·3266	+ 6	− 36	+ 129	13·9736	0	− 20	+ 19
12	8·5	13·4709	− 9	+ 61	+ 36	14·9851	− 6	− 7	+ 68
24	9·3	14·0366	− 6	− 55	+ 35	14·3990	0	0	+ 34
59	9·9	14·0400	...	...	+ 9	18·0796	...	...	− 14
31	10·5	14·1177	...	...	− 114	14·3286	...	...	− 12
6	9·6	14·5964	+ 2	− 180	+ 10	12·2185	− 2	− 21	+ 14
36	9·0	14·9075	+ 12	+ 64	+ 66	16·6535	+ 2	− 17	+ 15
20	9·4	15·1137	+ 16	− 64	− 54	15·6679	+ 3	− 54	− 5
21	8·8	15·5648	− 4	+ 24	0	15·7096	− 3	− 28	0
43	9·2	15·8478	− 3	+ 10	+ 80	18·0786	+ 28	− 9	+ 62
19	8·9	15·8848	− 3	+ 33	+ 68	15·2879	− 38	+ 26	+ 18
33	10·5	16·3965	...	...	+ 14	14·9550	...	...	− 38
32	10·5	16·5076	...	...	+ 51	14·2746	...	...	+ 26
22	9·0	16·7186	+ 2	− 85	+ 6	13·4625	− 18	+ 29	+ 34
37	8·6	17·4410	+ 02	+ 54	+ 50	16·8966	+ 08	− 16	+ 39
62	10·9	17·8155	...	...	+ 250	12·8430	...	...	+ 115
65	10·3	17·9360	...	....	+ 264	10·7154	...	...	− 15
41	10·4	17·9974	...	...	0	15·2052	...	...	+ 10

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On the Distance of the Galactic Star-Clouds.

By Dr. C. Easton.

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In a recent paper on the distance of the Milky Way, A. Pannekoek * finds for the parallax of the bright galactic aggregations about β Cygni $\pi = 0''{\cdot}000025$, and for that of the Aquila stream $\pi = 0''{\cdot}000016$, corresponding to distances of 40,000 and 60,000 parsecs respectively. These results are in accordance with the well-known conclusions of Shapley, in his seventh paper on the "Colours and Magnitudes of Stellar Clusters." In a former paper,†

* "The Distance of the Milky Way," *M.N.*, 79, No. 7 (1919 May), 500.

† "Researches into the Structure of the Galaxy," *Proc. Amsterdam Ac. Sc.*, 1910, p. 239.

Pannekoek had reached the conclusion that "no organic relation exists between the mass of the stars from the 9th down to about the 11th magnitude, and the star-clouds which form the Milky Way." Similarly, H. Nort* found that the phenomenon of the Milky Way is not reflected in the distribution of the stars from $9^{m}\cdot0$ down to $11^{m}\cdot0$.

Now all this seems to be incompatible with the conclusions I arrived at,† as far back as 1894, from a statistical investigation of about the same parts of the galactic zone which were studied by Pannekoek, and also with the result of a less detailed investigation of the whole northern Milky Way, published some years afterwards.‡ In the first-named of these papers I found that a correlation between the distribution of the relatively bright stars and the details of the galactic phenomenon is already indicated in magnitude 8·5 or 9·0 of the Bonn Durchmusterung, at any rate in the Aquila and Cygnus regions, although the galactic phenomenon itself is of course principally or almost wholly due to stars of much fainter magnitudes. Further, I wrote: "Though this correlation only manifests itself clearly in the groups of magnitude 8·5 and fainter, even a cursory glance at the Bonn charts and the photographs of the Milky Way must convince us that a great number of much more brilliant stars are intimately related to the galactic agglomerations in those parts of the zone."§

These results and the statistical data from which they were derived have been quoted several times lately, *i.e.* by Eddington,‖ and as Newcomb also had arrived at results which pointed in the same direction,¶ it seemed worth while to take the matter in hand afresh, and to elucidate the problem by somewhat different methods, investigating (1) the star-density, (2) the distribution of spectral types, (3) the distribution of proper motions—over the dark as well as over the bright patches of the Milky Way.

If we observe an uncommonly great number of relatively bright stars in the direction of a galactic cloud—where the very faint and generally more distant stars are apparently crowded,—we may suppose—

1. That an uninterrupted column of stars, or a cone with its apex in the eye of the observer, extends itself in that direction;

2. That a chance condensation of near stars coincides with a "galactic" condensation of stars, much more distant, without their being in any way physically connected;

3. That it is the galactic condensation itself which, though not

* "The Harvard Map of the Sky and the Milky Way," *Rech. Astron. Utrecht*, 7 (1917), 129.

† "Sur la distribution appar. des étoiles . . .," *A.N.*, 3270; "On the Distribution . . .," *Aph. J.*, 1 (1895 March), 216.

‡ "Sur la distribution de la lumière galactique . . .," *Memoirs Amsterdam Ac. Sc.*, 8, No. 3 (1903); *A.N.*, No. 3803.

§ *A.N.*, 3270, p. 87.

‖ *Stellar Movements and the Structure of the Universe* (1914), p. 235.

¶ *The Stars*, p. 269.

necessarily in organic relation with the "field stars" or "foreground stars," produces an *apparent* excess of near-by stars, a certain number of the brightest cloud-stars being added to those stars which owe their high apparent luminosity to their small distance from the Sun.

The first supposition may correspond to the reality in some cases, where we see the stratum foreshortened, but this disposition of the stars cannot be a common one, as this would imply an utterly improbable "bristling up" of the galactic layers in several directions, from the Sun outward. The second supposition becomes obviously improbable if the coincidence should repeat itself several times, the more so if the galactic condensations and the corresponding condensation of relatively bright stars have an appreciable galactic latitude. Now, though we observe great differences in this respect between different parts of the galactic zone, the correlation of relatively bright stars with galactic clouds appears to be by no means an uncommon occurrence, it manifests itself quite distinctly in several parts of the Milky Way.*

The third supposition implies that the galactic cloud or stratum (be it unconnected or only indirectly connected with the star-cluster or star-field surrounding our Sun), although perhaps very distant, cannot be—when compared to the mean distance of the "field-stars" which constitute the great majority of the brighter stars—so remote as not to exercise any influence, by means of its most luminous components, on the mean magnitude, the mean proper motions, etc., of the "brighter" stars situated between the galactic agglomerations and our Sun.

Now if, in most cases, an observed excess in the number of relatively bright stars, for a given area, must be really ascribed to very distant "cloud-stars," this excess in density must be accompanied by an excess in very small parallaxes, very small proper motions, and also of first-type stars, for the same area, as of course the B and A stars, by their great intrinsic luminosity, are singled out from the mass of cloud-stars.

To test these suppositions, we will now compare the brighter and denser parts of the Milky Way with the dark parts and void regions, selecting those regions where the contrast in general brightness is as great as possible. In the darkest parts of the zone, where we have only to reckon with the "field-stars" in our neighbourhood, we must expect to find in general—if our third supposition holds good—for the relatively bright stars, say to the ninth magnitude: a smaller value for the star-density, a greater mean parallax, greater mean proper motions, and a smaller proportion of B and A stars.

The most delicate part of this investigation consisted in the demarcation of the bright and dark regions of the Milky Way. For the naked eye and on the "isophotic chart" of the northern

* See the statistical researches quoted in the former notes; also Plassmann's *Himmelskunde* (1913), p. 442.

galactic zone * the contrasts are often striking enough and the demarcation seems easy; the photographs of the Milky Way,† however, show that in many cases regions almost void of stars are intermingled with true "galactic" formations.

If the data for proper motions in general are already pretty abundant, only a few catalogues may be considered sufficiently trustworthy for a statistical survey of individual proper motions. I decided to use only two publications, which contain a fairly great number of p.m.'s:

The Greenwich Catalogue, 1910, part ii.,‡ for the galactic zones in Cygnus and Taurus, between $\delta + 24^\circ{\cdot}0$ and $\delta + 32^\circ{\cdot}0$;

The Revised Groombridge Catalogue, 1905, for several parts of the northern Milky Way which have polar distances not exceeding $38^\circ{\cdot}0$.§

The Greenwich zone may be considered complete down to $9^m{\cdot}0$, and contains a considerable number of fainter stars; the Groombridge stars are far less numerous, in particular for the fainter stars, their average magnitude being $7{\cdot}0$.

In the *Groombridge Catalogue* the spectral class is indicated summarily (I. and II.); the *Greenwich Catalogue* gives subdivisions. Those parts of the revised *Draper Catalogue* which are to hand at present (1920 November) have been utilised for a more detailed investigation of the spectral class in relation to proper motion, in the dark and bright parts of the Perseus region, but only to give a specimen of what may be expected from a general investigation of this kind, which cannot be undertaken before the publication of the *Draper Catalogue* is completed.

The star-density has been computed for all the regions investigated.

I decided to limit the present researches to the above, and not to include the parallaxes, these data being as yet too scanty.

The galactic latitude of the regions selected in no case exceeds + or -10°; between those limits the well-known dependency of the amount of p.m. on the galactic latitude can have no appreciable influence, except perhaps in the Taurus region. The proper motions are, of course, also dependent on the stream motion and on the distance from the apex of solar motion; the first factor could not be taken into consideration, but to minimise the influence of the parallactic motion every region has been considered separately, only the bright and dark parts of the same region being compared *inter se*.

Marth's position of the galactic N. pole ‖—$\alpha = 190^\circ{\cdot}0$, $\delta = +30^\circ$ ($1880{\cdot}0$)—has been adopted. The difference with Gould's more

* *Memoirs Amsterdam Ac. Sc.*, 8, No. 3.

† In particular: *Publications of the Lick Observatory*, 11, 1913; *cf.* Easton, *Aph. J.*, 37, 2 (1912).

‡ *Greenwich Catalogue of Stars for* 1910·0: Part ii., Stars in the Zone $+24^\circ{\cdot}0$ to $+32^\circ{\cdot}0$; London, 1920.

§ Dyson and Thackeray, *New Reduction of Groombridge's Catalogue of Circumpolar Stars*, London, 1905.

‖ *M.N.*, 53, Nos. 2, 6.

generally used position—$\alpha = 190^\circ\ 20'$, $\delta = +27^\circ\ 21'$—can amount for some parts of the zone to 3 degrees, but this is immaterial to our purpose.

In each region the stars have been divided into three or four classes according to magnitude, the limits being chosen so as to facilitate a comparison with Schouten's investigation of stars of a given magnitude and proper motion, in five zones parallel to the galactic plane.*

The following is a list of the regions investigated and of their areas:—

1. *β Cygni region* (Greenw. Cat.).
   1. Dark: $\alpha\ 19^h\ 36^m, 48^m$; $\delta + 24^\circ\ 0' + 27^\circ\ 0'$—$19^h\ 48^m, 20^h\ 4^m$; $\delta + 26^\circ\ 0' + 28^\circ\ 0'$—$20^h\ 8^m, 16^m$; $\delta + 30^\circ + 32^\circ\ 0'$.
   2. Bright: $\alpha\ 19^h\ 24^m, 28^m$; $\delta + 27^\circ\ 0' + 30^\circ\ 0'$—$19^h\ 28^m, 36^m$; $\delta + 26^\circ\ 0' + 32^\circ\ 0'$—$19^h\ 36^m, 46^m$; $\delta + 27^\circ\ 0' + 32^\circ\ 0'$—$19^h\ 46^m, 56^m$; $\delta + 29^\circ\ 0' + 32^\circ\ 0'$—$19^h\ 56^m, 20^h\ 0^m$; $\delta + 30^\circ\ 0' + 32^\circ\ 0'$.

2. *γ–α Cygni region* (Groombr. Cat.).
   1. Dark: $\alpha\ 20^h\ 12^m, 20^h\ 48^m$; $\delta + 41^\circ\ 0' + 44^\circ\ 30'$—$20^h\ 24^m, 20^h\ 48^m$; $\delta + 38^\circ\ 0' + 41^\circ\ 0'$—$20^h\ 48^m, 21^h\ 12^m$; $\delta + 47^\circ\ 30' + 54^\circ\ 0'$—$20^h\ 48^m, 21^h\ 12^m$; $\delta + 40^\circ\ 0' + 44^\circ\ 0'$.
   2. Bright: $\alpha\ 19^h\ 48^m, 20^h\ 12^m$; $\delta + 38^\circ\ 0' + 44^\circ\ 30'$—$20^h\ 12^m, 24^m$; $\delta + 38^\circ\ 0' + 41^\circ\ 0'$—$20^h\ 48^m, 21^h\ 12^m$; $\delta + 44^\circ\ 0' + 47^\circ\ 30'$—$20^h\ 38^m, 48^m$; $\delta + 44^\circ\ 30' + 47^\circ\ 0'$—$21^h\ 24^m, 22^h\ 0^m$; $\delta + 45^\circ\ 0' + 47^\circ\ 0'$.

3. *Cepheus-Cassiopeia region* (Groombr. Cat.).
   1. Dark: $\alpha\ 21^h\ 13^m, 30^m$; $\delta + 51^\circ\ 30' + 56^\circ\ 0'$—$21^h\ 30^m, 22^h\ 0^m$; $\delta + 53^\circ\ 30' + 56^\circ\ 0'$—$22^h\ 0^m, 20^m$; $\delta + 58^\circ\ 0' + 61^\circ\ 0'$—$22^h\ 20^m, 40^m$; $\delta + 58^\circ\ 0' + 64^\circ\ 0'$—$22^h\ 40^m, 50^m$; $\delta + 59^\circ\ 0' + 64^\circ\ 0'$—$22^h\ 50^m, 23^h\ 0^m$; $\delta + 60^\circ\ 0' + 64^\circ\ 0'$—$23^h\ 0^m, 28^m$; $\delta + 61^\circ\ 0' + 64^\circ\ 0'$—$0^h\ 0^m, 30^m$; $\delta + 63^\circ\ 30' + 65^\circ\ 0'$—$0^h\ 30^m, 1^h\ 0^m$; $\delta + 62^\circ\ 0' + 65^\circ\ 0'$—$1^h\ 0^m, 28^m$; $\delta + 62^\circ\ 0' + 64^\circ\ 0'$.
   2. Bright: $\alpha\ 21^h\ 13^m, 30^m$; $\delta + 47^\circ\ 0' + 51^\circ\ 30'$—$21^h\ 30^m, 22^h\ 0^m$; $\delta + 47^\circ\ 0' + 53^\circ\ 0'$—$22^h\ 0^m, 30^m$; $\delta + 50^\circ\ 0' + 56^\circ\ 0'$—$22^h\ 50^m, 23^h\ 0^m$; $\delta + 56^\circ\ 0' + 60^\circ\ 0'$—$23^h\ 48^m, 0^h\ 30^m$; $\delta + 60^\circ\ 0' + 63^\circ\ 30'$—$0^h\ 30^m, 1^h\ 24^m$; $\delta + 60^\circ\ 0' + 62^\circ\ 0'$.

4. *Perseus–Auriga region* (Groombr. Cat.).
   1. Dark: $\alpha\ 2^h\ 36^m, 3^h\ 0^m$; $\delta + 51^\circ\ 0' + 56^\circ\ 0'$—$3^h\ 0^m, 38^m$; $\delta\ 51^\circ\ 0' + 57^\circ\ 30'$—$3^h\ 38^m, 4^h\ 10^m$; $\delta + 53^\circ\ 30' + 60^\circ\ 0'$—$4^h\ 18^m, 30^m$; $\delta + 47^\circ\ 0' + 50^\circ\ 0'$—$4^h\ 20^m, 40^m$; $\delta + 52^\circ\ 0' + 56^\circ\ 0'$.

* W. J. A. Schouten, *On the Determination of the Principal Laws of Statistical Astronomy*, Amsterdam, Kirchner, 1918, p. 39.

2. Bright: $\alpha\ 3^h\ 0^m, 30^m$; $\delta + 47^\circ\ 0' + 50^\circ\ 30'$—$3^h\ 0^m, 30^m$; $\delta + 58^\circ\ 0' + 60^\circ\ 0'$—$3^h\ 50^m, 4^h\ 18^m$; $\delta + 48^\circ\ 0' + 52^\circ\ 0'$—$4^h\ 0^m, 34^m$; $\delta + 40^\circ\ 0' + 47^\circ\ 0'$—$4^h\ 48^m, 5^h\ 12^m$; $\delta + 40^\circ\ 0' + 47^\circ\ 0'$.

5. *Taurus region* (Greenw. Cat.).

1. Dark: $\alpha\ 4^h\ 24^m, 52^m$; $\delta + 29^\circ\ 0' + 32^\circ\ 0'$—$4^h\ 40^m, 8^m$; $\delta + 27^\circ\ 0' + 29^\circ\ 0'$—$4^h\ 56^m, 5^h\ 20^m$; $\delta + 24^\circ\ 0' + 27^\circ\ 0'$.

2. Bright: $\alpha\ 5^h\ 32^m, 44^m$; $\delta + 24^\circ\ 0' + 32^\circ\ 0'$.

The area under investigation is equal to 667·8 square degrees: 330·7 in the dark, 337·1 in the bright parts of the Milky Way. The area of the galactic zone confined between the limits 0° to ±10° being 3581·9, it follows that our area occupies about 19 hundredths of the northern Milky Way. It contains 1311 stars: 491 in the dark, 820 in the bright parts.

A notable difficulty, always present in statistical researches of this kind, lies in the exclusion of excessive proper motions. *Some* kind of exclusion must, of course, be made. I decided to work out the data by two methods—

A: all stars with a total p.m. $>9''{\cdot}9$ p. century excluded;

B: no stars rejected, but p.m. $>9''{\cdot}9$ p. century reduced to $10''$ (μ tot. cannot exceed $10''$).

A determination of "μ median" has also been made. The frequency of the values of μ between $0''$ and $0''{\cdot}5$, $0''{\cdot}5$ and $1''{\cdot}0$, $1''{\cdot}0$ and $1''{\cdot}5$, etc., having been taken as abscissæ, the number of stars for which the amount of μ is smaller than the value of the abscissa being taken as ordinates, a curve was derived for each of our regions, from which μ median could be taken. The results are not given here, as they do not differ materially from those reached by the other methods.

The total proper motion had to be computed from the p.m.'s given in both co-ordinates in the catalogues.

In the three following tables the principal results of this investigation have been embodied.

Table I. gives, for the five regions, the star-density, and the ratio of Type I.: all stars for which the spectral type is known. With the exception of the Perseus region, the spectral indications are those of *Harvard L*, which shows some discrepancies with the new *Draper Catalogue*. In Table II. the few Groombridge stars fainter than $8^m{\cdot}99$ have been added to the class $8^m{\cdot}0 - 8^m99$. In Table III. each column contains two rows of values (number of stars bracketed); reading from top to bottom, those values should be comparable if the regions around the poles of the Milky Way were identical, as to the proportion of slow and fast proper motions, with the dark parts of the Milky Way, where the visual ray encounters no galactic aggregations accessible to our instruments. Van Rhijn's values,* derived from his table 3, are not, strictly speaking, comparable with ours, his limit for magnitude being 7·45,

* Kapteyn and Van Rhijn, *Publ. Astron. Laboratory at Groningen*, No. 30, table iii., p. 77.

and for proper motion 4″, but rather than venture an interpolation I preferred to give them as they stand. From Schouten's tables 18 and 19 the values given in our Table III. could easily be computed. [There are some misprints in Schouten's tables: the dots in the numbers greater than 1000 must be cancelled.]

TABLE I.

Areas and Numbers, Star-density, Percentage Type I.

Region.	Fraction of Total Number of Stars.	Area in sq. d.		Numbers.		Star-density.		Perc. Type I.	
		Dark.	Bright.	Dark.	Bright.	Dark.	Bright.	Dark.	Bright.
β Cygni	38·9	18·7	32·2	160	342	8·6	10·6	59	65
γ-α Cy.	14·3	79·7	67·7	74	110	0·9	1·6	77	49
Ceph.-Cass.	11·8	85·9	99·9	67	120	0·8	1·2	66	72
Pers.-Aur.	9·8	99·7	116·1	34	79	0·3	0·7	35	70
Taurus	25·2	46·7	21·2	156	169	3·3	8·0	44	58

TABLE II.

Values of $\bar{\mu}$ in Dark and Bright Parts of the Galaxy.

Region. \ m	A. $\mu \geqq 10''$ excluded.					B. $\mu > 10'' = 10''$.				
	>7·0.	7·0–7·99.	8·0–8·99.	≦9·0.	Σ.	>7·0.	7·0–7·99.	8·0–8·99.	≦9·0.	Σ.
β Cygni D.	3″7 (9)	2″3 (21)	2″8 (62)	2″7 (66)	2″7 (158)	4″3 (10)	2″7 (22)	2″8 (62)	2″7 (66)	2″8 (160)
β Cygni B.	3″0 (23)	2″7 (30)	2″8 (129)	3″2 (151)	3″0 (333)	3″4 (24)	2″7 (30)	3″0 (133)	3″4 (155)	3″2 (342)
γ-α Cygni D.	3″0 (28)	3″0 (29)	2″5 (10)	...	2″9 (67)	3″6 (31)	3″5 (31)	3″8 (12)	...	3″6 (74)
γ-α Cygni B.	2″3 (30)	2″7 (36)	3″0 (43)	...	2″6 (109)	2″3 (30)	2″7 (36)	3″2 (44)	...	2″7 (110)
Ceph.-Cass. D.	3″0 (22)	3″1 (32)	2″7 (11)	...	3″0 (65)	3″6 (24)	3″1 (32)	2″7 (11)	...	3″3 (67)
Ceph.-Cass. B.	2″6 (33)	2″2 (41)	2″9 (37)	...	2″5 (111)	3″5 (38)	2″7 (44)	3″1 (38)	...	3″1 (120)
Pers.-Aur. D.	3″4 (18)	2″7 (9)	3″9 (6)	...	3″3 (33)	3″7 (19)	2″7 (9)	3″9 (6)	...	3″5 (34)
Pers.-Aur. B.	3″2 (37)	4″3 (15)	3″2 (21)	...	3″3 (73)	3″7 (40)	5″0 (17)	3″5 (22)	...	3″9 (79)
Taurus D.	3″6 (8)	2″8 (18)	3″8 (48)	3″8 (67)	3″7 (141)	5″7 (12)	3″2 (19)	4·5 (54)	4″1 (71)	4″2 (156)
Taurus B.	2″5 (12)	3″2 (25)	2″4 (69)	3″0 (59)	2″7 (165)	2″5 (12)	3″6 (26)	2″5 (70)	3″4 (61)	2″9 (169)

TABLE III.

Percentage of Stars with $\mu > 3''$ for $m > 8^{\cdot}0$ and $m \leqq 8^{\cdot}0$.

Each column contains:
Left: Dark parts Ea., Zone V. Sch., Zone III. v. Rhijn.
Right: Bright parts Ea., Zone I. Sch., Zone I. v. Rhijn.

Auth.	$m > 8^{\cdot}0$.		$m \leqq 8^{\cdot}0$.		All Magn.	
Ea., β Cygni	41 (13)	39 (22)	38 (49)	44 (125)	39 (62)	43 (147)
Ea., γ-α Cygni	50 (31)	35 (23)	58 (7)	41 (18)	51 (38)	37 (41)
Ea., Ceph.-Cass.	44 (25)	36 (30)	45 (5)	39 (64)	44 (30)	38 (94)
Ea., Pers.-Aur.	43 (12)	60 (35)	67 (4)	48 (10)	47 (16)	57 (45)
Ea., Taurus	48 (15)	45 (17)	62 (77)	38 (50)	59 (92)	40 (67)
Easton, weighted means	46 (227)	42 (300)	50 (282)	42 (502)	48·4 (509)	42·2 (802)
Schouten	67·5 (52)	47·0 (85)	59·5 (260)	45·2 (684)	60·7 (312)	45·4 (769)
v. Rhijn, $m \gtrless 7^{\cdot}45$, p.m. $> 4''$	53·0 (2160)	34·2 (2709)	40·6 (11819)	24·6 (17665)	42·1 (14078)	25·6 (20374)

General Remarks.

1. Table I. shows that in all five regions, without exception, the density for the relatively bright stars is greater in the bright than in the dark parts of the portions of the Milky Way investigated. This is in accordance with our previous results; but it does not imply that the conclusion holds good for the whole galactic zone and for the same class of magnitude.

2. In four regions the percentage of first-type stars is greatest in the bright parts, the exceptional case relating to only $\frac{1}{7}$ part of the total number of stars considered.

3. From Table II. it follows that in the majority of cases (10 out of 17, B) the p.m.'s are generally larger in "dark" than in "bright"; in two cases there is but little difference; in five cases the faster p.m.'s are found in "bright."

If we consider the regions without distinction of magnitude classes, the preponderance lies in three cases with the dark parts, in one case with the bright part; in another case the result is dubious for A, towards bright for B.

4. From Table III. we see that Schouten's values in the second column are not very different from the proportion shown by Easton (weighted means), the number of stars being somewhat higher for Schouten's $< 8^{m}{\cdot}0$. Van Rhijn's numbers ($\pm 20^{\circ}$ galactic latitude)

are considerably greater. Though the star-density in the dark patches of the Milky Way is about three times greater than around the galactic poles, the approach to equality of Easton's and Schouten's values for the proper motions seems somewhat difficult to reconcile with the idea of a "solar cluster" much more extensive in the galactic plane than at right angles thereto; more data and more refined proper motions are, however, necessary before we can reach a conclusion.

Special Remarks.

It seems inadmissible to attribute the relative superiority of the bright parts in first-type stars to the Gould-Shapley "belt of bright stars";* the position of the portions of the Galaxy here investigated with regard to the galactic plane is not in agreement with such a supposition.

With the sole exception of the Perseus-Auriga region, which contains only 10 per cent. of the total number of stars investigated, the excess of large proper motions in the dark parts becomes less apparent as we proceed to fainter stars—a curious particularity, but which *may* be caused by the less trustworthy results for the p.m. of the fainter stars.

The drawbacks of an uncertain delimitation of dark and bright patches and of the small number of bright stars in the dark parts make themselves particularly felt in the β Cygni and Perseus regions.

On the other hand, our Taurus region, where the preponderance of the dark over the bright regions in great proper motions amongst the relatively bright stars is most pronounced, must be considered somewhat exceptional, about 20 per cent. of the dark region being occupied by patches where a great deficiency of stars of all magnitudes seems to be caused by absorbing matter.†

It seems to me, however, that in no case can these disturbing factors have a deciding influence on the result. It should be remarked, first, that the preponderance in proper motion for Taurus "dark" compared to Taurus "bright" is 1·6 for magnitudes $>9{\cdot}0$ and 1·2 for $m \leqq 9{\cdot}0$; second, that 65 per cent. of the stars in the bright part belong to the first type, against 44 per cent. in the dark part, although the general deficiency of the stars between R.A. 4^h and 5^h is certainly not less apparent in the G and K stars than in the Types B and A.

The β Cygni region is so near the solar apex that the individual ("peculiar") motions of the stars, and consequently the accidental irregularities, must play a great part in our statistics of this part of the Milky Way. But we observe a certain regularity in the growing excess of proper motion in the bright part, as we consider fainter magnitudes (Table II.), so this exception appears

* Shapley, in *Proc. Nat. Ac. Sci. Washington* (1919 Oct.), 5, 10.

† Barnard, *Astrophys. Journal*, 49, 1; Dyson and Melotte, *M.N.*, 80, 3; Pannekoek, *M.N.*, 79; *Proc. Amsterdam Ac. Sc.*, 19, 524, 622.

to be real; a preponderance of the dark part seems to be out of the question, at any rate. Here then, it would seem, we have a galactic aggregation so distant that no effect on the distribution of the bright stars can be detected, and this is one of the regions where Pannekoek found his enormous distances of several ten-thousands of parsecs.

This can hardly be, however, the true explanation of the exceptional behaviour of the β Cygni region. For not only is the density of the bright part of this region greater than that of the dark part (10·7 : 8·6), but the greatest values for the density of the relatively bright stars coincide almost exactly with the well-known β Cygni cloud of the Milky Way. Plotting of the stars grouped in smaller areas reveals this particular distribution, the more striking as the β Cygni cloud is separated from the galactic agglomerations around ζ Aquilæ by an area where the galactic light is very faint, and which stretches right across this part of the Milky Way. If we count the Greenwich stars between R.A. $20^h\ 0^m$, $21^h\ 0^m$, Dec. $+24°{\cdot}0$ to $+32°{\cdot}0$, in areas of 8 square degrees, we find that the five areas with highest mean star-density (1·22 to 1·46) are all situated in the region between β Cygni, 41 Cygni, and a point north of ϕ Cygni, where the Milky Way is also strongly condensed. Now it is obviously improbable that a real condensation of stars in the neighbourhood of the Sun and an extremely distant galactic cloud should be seen almost exactly in the same direction without their being physically related.

Neither can we account for this remarkable distribution of densities and p.m.'s by the supposition—though probable in itself *—that the northern (Cygnus) branch of the Milky Way is nearer to us than the southern (Aquila) branch, and that this phenomenon is reflected in the p.m.'s of the brighter stars. For if we compare the Greenwich stars in the northern part of this zone, R.A. $19^h\ 18^m$ to $19^h\ 28^m$, Dec. $+26°{\cdot}0$ to $+32°{\cdot}0$ (118 stars), with those projected on the southern branch of the Milky Way, R.A. $20^h\ 36^m$ to $20^h\ 46^m$, Dec. $+25°{\cdot}0$ to $+32°{\cdot}0$ (119 stars), we get:

		m > 8·6.	m 8·6–9·0.	m < 9·0.	Type I.	Type II.
N.	μ_α	·s0016	·s0013	·s0014	35	17
	μ_δ	·″019	·″013	·″017		
S.	μ_α	·s0013	·s0016	·s0014	21	29
	μ_δ	·″018	·″015	·″015		

No systematic difference is shown in these values.

On the other hand, the distribution of the spectral types over this part of the zone is very irregular.

The most plausible explanation of the peculiarities of the β Cygni region appears to be, that in the direction of β Cygni a *not very distant*—or swiftly moving—cloud of galactic stars is

* "Sur la distribution de la lumière galactique . . .," *Memoirs Amsterdam Ac. Sc.*, 8, No. 3 (1903); *A.N.*, No. 3803.

seen projected on another galactic stratum, situated much farther away, and contributing only very small p.m.'s to the mass of the stars seen in the direction of the relatively dark patches.*

The Perseus-Auriga region also forms an exception to the general rule, but the distribution of the p.m.'s over this area seems to be influenced mainly by a number of swift moving stars of the 7th magnitude in the bright parts (Table II.). The number of stars in this region is, moreover, too small to give it much weight in the general considerations. The inclusion of 17 Porter stars † in the dark parts does not appreciably alter the result.

The stars known to belong to the moving cluster of Perseus have been excluded.

For this region we have considered the spectral types A and B (*Draper Catalogue*) separately. The stars of various types show the following average centennial p.m.'s ($\mu > 10 = 10$); the number of stars being bracketed:

Pers.-Aur. region.	B.	A.	F–M.
Dark	18	29	46
	(8)	(11)	(16)
Bright	33	35	41
	(15)	(28)	(37)

In the dark parts, the F–M's show considerably greater p.m.'s; in the bright parts this relative superiority is much less. From Boss—for 0^m to 6^m—we get the ratio $\bar{\mu}B : \bar{\mu}A : \bar{\mu}F \ldots = 6 : 10 : 16$; the B stars in the dark parts of Perseus conform to this proportion, but in "bright" they move much more swiftly. Perhaps a number of relatively near B and A stars are projected on the galactic strata in this part of the sky.

Conclusions.

The correlation of the distribution of relatively bright stars with the position of the galactic agglomerations is certainly not a phenomenon which holds good for *all* parts of the Milky Way. On the other hand, the cumulation of evidence seems to point rather convincingly to the conclusion, that in several parts of the zone the galactic aggregations affect the density, the proper motions, and the spectral type of the relatively bright stars nearer to our Sun. Thus, unless we are prepared to assign to a considerable number of "cloud stars" intrinsic brilliances of a million or ten million times that of the Sun, it is difficult to conceive how those galactic clouds can be situated at distances of the order of 50,000, or even 10,000 parsecs.

* In the bright part near β Cygni we find five stars (Nos. 9328, 9416, 9578, 9585, 9589 Greenw.), with big proper motions (μ tot. 216, 228, 213, 234, 259) of the same order but of various direction. The exclusion of these stars would not, however, affect our results.

† *Publ. Cincinnati Obs.*, 18, iv.

My thanks are due to several astronomers for help and advice in the course of this investigation; especially to Professor J. C. Kapteyn for his advice in the choice of the data, and to Mr. W. J. Luyten for his share in the computations. I am under special obligation to Sir F. W. Dyson for putting at my disposal the advance sheets of the recent publication of the Greenwich Observatory, and to Professor Max Wolf for taking a couple of photographs to supplement Professor Barnard's beautiful collection of the Lick Observatory.

Amsterdam:
1920 *December.*

The Astrophysical Problem of Variable Stars.

By J. G. Hagen, S.J., For. Assoc. R.A.S.

1. If eclipsing variables are set apart as only apparently variable, all the remaining physically variable stars may be divided into two classes, those of long and those of short period, the separating line being from three to four months. This classification comprises all the types thus far known, even the irregular and the temporary stars.

Taking Mira Ceti and δ Cephei as the representatives of long-period and short-period variables respectively, the irregular stars of the α Orionis type may, with good reason, be considered as extreme cases of longest period, while those of the U Geminorum type are but modifications of the δ Cephei class; and so are temporary stars, as the writer will show in another place. As to the cluster type, its physical cause cannot be essentially different from that of δ Cephei. Thus the whole problem centres about the two representatives o Ceti and δ Cephei.

2. About δ Cephei we have two theories, the binary and the pulsation theory, one of which must be the true solution.

(*a*) The pulsation theory has been so thoroughly developed that it only remains to show how the binary answers as well all the facts. It admits of a double aspect, one geometrical and one physical.

From a merely geometrical point of view it suffices to suppose that the secondary companion of the system is in some way capable of causing on the principal star an eruption of light by the mere fact of approach. This supposition, simple as it appears, entails a number of consequences. It implies that the eruption is transitory and local, that it becomes the stronger the nearer the approach, that its maximum lags behind the passage of shortest distance, and that its rise is somewhat more rapid than its abatement.

Evidently the eruption on the principal component is best visible to the observer, when the orbit is very excentric, when the stars pass their periastra or somewhat later, and when the secondary companion is between the illuminated star and the observer. All these consequences correspond to what observation and calculation

have established as the characteristic features of δ Cephei variation. The light-curve, with its short rise and longer descending branch, not only answers the explanation, it also gives the very clue to the outstanding question, why the mass of the secondary companion is, in all known δ Cephei stars, small compared to the principal component. Suppose the two companions to be of nearly equal mass, the eruption of light on the one could not remain local, it would develop into a conflagration expanding over the whole surface. The star might still appear variable, but its light-curve would not be that of the δ Cephei type. Whether it represents the ζ Geminorum type, which is commonly classed with that of δ Cephei, cannot be decided for the scantiness of the material, only seven ζ Geminorum stars being as yet known.

Since, then, the δ Cephei light-curve supposes a smaller mass in the companion that causes the eruption, it becomes intelligible why only one spectrum is seen and why the light-range is confined to about one magnitude.

(*b*) Thus far the δ Cephei theory is mainly geometrical; it remains to interpret it physically. That there are cosmic masses which become luminous by the mere approach to a star is demonstrated to the eye by the existence of comets. Whether the comets, at their aphelia, are lucid or obscure is not known. When they come within the radiating influence of the sun, their small mass becomes entirely permeated by light, but as a rule in such fashion that the side facing the sun is more brilliant than the opposite one, that the maximum brilliancy takes place shortly after perihelion passage, and that the fading of the light is slower than its increase. Tails develop in most, but not in all, cases.

Now let the relative masses be reversed and suppose a star, possessed with all the radiant energy of our sun, to come near a cometary mass of giant proportions. By mutual attraction they will revolve around their common centre of gravity, which may well be situated within the comet. The δ Cephei stars are known to be giant stars. Their average excentricity is 0·3, greater than that of the major planets but smaller than that of periodic comets, which is 0·7, so that their orbits may be compared to those of the minor planets. Being thus permanently under the radiating influence of the star, the cometary mass is probably lucid all through, though more so on the side turned toward the stellar companion. Since the variation of the δ Cephei stars is nearly one magnitude, which means that, at maximum, we get 2·5 times as much light as at minimum, we have to assume that, near perihelion, the cometary mass becomes at least twice as bright as near aphelion. Here it is to be noticed that, when we see the star at minimum, we get less than the average aphelion light, because we see that part of the mass which is averted from the secondary companion.

As long as the masses of the two components are very unequal, as is supposed, the increased radiating influence of the small star at perihelion passage can only have a transitory, and hence a merely local, effect, which will gradually fade away as the two bodies get

further apart. It is quite natural also that the surface equilibrium of the cometary mass becomes disturbed, and that the fading light is accompanied by undulations, exactly as we see them in the descending branches of the light-curves.

Thus the cometary theory, as it may be called, explains the δ Cephei variation as well as the pulsation theory. It certainly has one advantage over the latter in that it rests on a well-known analogous fact, whilst of pulsations maintaining themselves for centuries in single bodies we have no visible example.

3. The problem of the long-period variables is different from, though not altogether independent of, that just considered. If the discrepancies between the o Ceti and the δ Cephei types are passed in review, such as range of variation, shape of light-curves, character of minima, inflexions before or after maxima, secular or periodic terms of recurrence, frequency maxima of periods, colour and spectra, and finally galactic distribution, they appear as progression rather than as opposition—progression from a less developed state, as it seems, to a more advanced one.

If this view is correct, then the causes of light-variation in the two classes of stars must be substantially identical; in other words, the variability of all the stars of whatever period, short or long, must be explained either by internal pulsations or by the binary hypothesis, according as the one or the other theory proves to be the correct one.

In any case, the hope is strengthened that the new science of variable stars will finally have to deal with one single astrophysical problem.

Vatican Observatory:
1920 *Dec.* 25.

The Circumstances of the Perihelion Passage of Pons-Winnecke's Comet in June 1921. By A. C. D. Crommelin.

It seems appropriate to draw attention to the prospects of a meteor-shower from this comet occurring about June 27 next. This comet is of unusual interest from the large progressive changes in its elements that have taken place since its discovery. These changes are due, in the main, to perturbations by Jupiter, and it will be remembered that the value of Jupiter's mass deduced from them by von Haerdtl was given a high weight by Newcomb when forming the adopted planetary masses for his new tables (*Fundamental Constants of Astronomy*, p. 97).

A century ago the perihelion distance of the comet was 0·77, but it has now increased to unity or slightly greater, and as the perihelion point is close to the descending node it follows that the orbit of the comet makes an extremely close approach to that of the earth. When an unexpected shower of meteors from a radiant in Bootes occurred in June 1916, its connection with this

comet was quickly pointed out both by Mr. Denning and Dr. Olivier, the latter publishing his results in *M.N.*, 77, 71.

The conditions next June promise to be more favourable than in 1916, for the double reason that the descending node will probably lie nearer to the earth's orbit, and that the comet will be much closer to the node when we cross the track. In 1916 perihelion passage was $9\frac{1}{2}$ months before the shower, but next June I do not think that it will be more than a fortnight before. The difficulty in making an exact forecast is that the comet made one of its close approaches to Jupiter during the last revolution, and the perturbations have not been calculated, or at least not published. Since the comet's period is now very nearly half that of Jupiter, the perturbations should bear a considerable resemblance to those of two revolutions earlier. I have made use of this fact in deducing rough elements for the next return. The following table gives the elements at various returns, also those estimated for 1921, and those of the comet 1766 II.

T.	ω.	Ω.	*i*.	*q*.	Period.	Interval.
	° ′	° ′	° ′		d	d
1766 Apr. 27·0	177 2	74 11	8 2	0·3990	1835	
1819 Jul. 18·9	161 30	113 11	10 43	0·7737	2052	
1904 Jan. 21·24	170 7	104 13	17 0	0·9234	2129	2132*
1909 Oct. 9·31	172 15	99 21	18 17	0·9728	2146	2088
1915 Sept. 2·25	172 20	99 23	18 18	0·9716	2144	2154
1921 June 15±10d	174	96	19 30	1·01	(2120)	(2113)

The comet passes the ascending node about four days after perihelion, and the earth passes it about June 28. Search ephemerides, based on the estimated elements, have been circulated, and are available for any who wish to search. The comet was found in 1915, five months before perihelion, being of mag. 16; as it is now nearer the earth than then, it should be detected in the next month or two.

I venture to open once more the question of the identity of comet 1766 II. with our comet. It was formerly thought that the perihelion distance was too small to make this probable; but now that we have seen such a large increase in this element in our own time, we are more prepared to admit its possibility, especially as the smaller inclination in those days would increase the Jupiter perturbations; there were close approaches to Jupiter in 1812 and 1800, and a fairly close one two revolutions earlier. In case of identity there must have been ten revolutions between 1766 and 1819, making the mean period 5·32 years, which happens to be the exact mean between the periods found in 1766 and 1819.

It seems to me that the question might be definitely settled by carrying back the perturbations, in a similar manner to that done for Halley's comet. I commend the suggestion to anyone

* This is interval between passages of 1898 and 1904.

with the necessary leisure. It would also incidentally settle the question whether the comet seen by Pons on three days in mid-February 1808 is our comet. He obtained only one record of position, on February $8^d\ 17^h$. He then made a sketch of the configuration with two nebulæ, which are obviously M 10 and M 12 in Ophiuchus. A curious point has arisen about this sketch, which is published in *Ast. Nach.*, 7, 114 (January 1829). Pons says it is *renversée*, which naturally would mean having the vertex at the bottom. Oppolzer, however, thought that it might mean that it was reversed from the position in which it was drawn at the telescope, noting that in this manner he got a better accord with the elements of our comet than taking it the other way round. Since the sketch had lain for twenty-one years unpublished, it is possible that Pons himself had forgotten how it was oriented.

The positions of the comet on the two hypotheses are:

	R.A.	S. Decl.
N. at top . .	$16^h\ 47^m\ 16^s$	$4^\circ\ 1'$
N. at bottom .	$16^h\ 36^m\ 21^s$	$1^\circ\ 11'$

If this is our comet, perihelion passage would have been early in April 1808, making the mean period between that and 1819 5·64 years, not an impossible amount. If computation of perturbations should indicate a perihelion passage in late March or early April 1808, the identity might be considered established. It will be remembered that isolated observations of Encke's comet were established in this manner as far back as 1786.

Added 1921 *January* 17.

Mr. F. Robbins suggested to me to apply Tisserand's criterion of identity to the comet 1766 II. I have accordingly formed the function

$$\frac{1}{a_0} + \frac{2\sqrt{p_0 a'}\cos i_0}{r'^2}$$

for several apparitions of the comet: a_0, p_0, i_0 indicate the semi-major axis, semi-latus rectum, and inclination to Jupiter's orbit of the comet's orbit. a', r' are the semi-axis-major of Jupiter's orbit and its radius in the direction of the comet's aphelion. The different values of this function are tabulated:

Year.	Value.
1766	·4884
1858	·5141
1904	·5176
1909	·5192
1915	·5192

It is to be noted that Burckhardt's elements, which I have used for 1766 II., are subject to considerable uncertainty, the observations being few and rough. Also there may well have been sensible perturbations by Venus, Earth, and Saturn in the interval 1766–1819. Hence the change in the Tisserand function does not seem to be so large as to be fatal to the hypothesis of identity.

Note on the Photography of Meteors. By J. Hargreaves.

The long-continued controversies on certain questions in the study of meteors make it evident that more accurate methods of observing are requisite. Various devices have been recommended as aids to visual observation, but none of these can entirely eliminate the errors of "estimation" of the path.

Though it is doubtful whether any photographic method would be more accurate in the determination of some elements such as the time of flight, magnitude, etc., yet it is certain that much greater accuracy would be obtained in the determination of radiants.

The essentials of a camera are that it should be capable of photographing a reasonable number of meteors, *i.e.* that it must cover a wide field, and also record faint objects. I also consider that it is desirable that the focal length should be as short as possible (if only for the sake of reducing the area of the photographic plate required).*

Experiments made with some second-grade lenses show that to photograph an object of stellar magnitude 0·0, moving at the rate of ten degrees per second, it is necessary to employ a lens of five inches clear aperture (working at about F3 or F4), the plates employed being the fastest normally manufactured. I propose, therefore, to construct a camera with several lenses (in order to cover a larger field) of clear aperture $5\frac{1}{2}$ or 6 inches. Such a lens should be capable of photographing meteors down to the second (visual) magnitude, provided that the passage is not abnormally rapid, for I consider that the average meteor is brighter photographically than visually. In the construction of the camera it will be necessary to limit the field, to ensure that the plate is everywhere well within the focal depth of the lens; but with more than one lens this should not unduly restrict the field. I do not propose to provide any mechanism for interrupting the trail, as this would reduce the power of the camera to record faint objects (a continuous line being more readily detected than a discontinuous one). In the

* For a point image, the speed of a lens of given clear aperture (in inches, say) is independent of the focal length; for a line image (such as a meteor trail) the speed is a function of the reciprocal of the focal length; and for a two-dimensional image (*e.g.* finite disc), a function of the square of the reciprocal.

matter of photographic plates, I find that the common "blue sensitive" plates will stand a very much longer exposure on a "luminous" night than will an orthochromatic plate of lower speed; and so if carefully selected each plate should stand an exposure of at least three-quarters of an hour (on an average night), and possibly much longer. I have not experimented on moonlit nights, but with more frequent changes of plates it should be possible to carry on the work with no very great inconvenience.

Micrometrical Measures of Double Stars (*15th Series*).
By Rev. T. E. Espin.

Name.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.	
	h m	° ′	°	″			1900	
Σ 156	1 40·2	+59 52	96·7	5·46	8·3 10·0	2	·058	
Espin 949	51·9	55 19	263·7	5·77	9·1 9·3	2	·993	
η Persei	2 43·4	55 29	300·2	28·03	3·7 8·5	2	·148	AB
(Ward)			113·9	4·85	10·5 11·2	2	·148	Cc
A.G.	3 32·8	60 20	312·4	6·52	8·7 8·7	3	·966	
Milburn 56	33·5	59 32	306·5	6·04	9·5 13·0	2	·993	
Kr. 23	4 22·2	55 17	128·5	4·66	9·2 9·4	2	·576	
Kr. 25	49·1	56 29	113·9	2·93	9·2 9·6	2	·170	
Kr. 26	5 13·7	55 49	71·5	9·12	9·2 9·4	2	·174	
Kr. 27	37·3	56 46	132·7	2·86	9·5 9·6	4	·152	
B.D. +56°·1056	37·5	56 40	328·5	2·21	9·4 10·5	2	·152	
Σ 934	6 30·8	55 8	328·2	3·70	8·9 9·2	2	·202	
Σ 958	39·8	55 50	256·3	5·01	6·5 6·6	2	·170	
Σ 1062	7 14·7	55 28	314·5	14·83		1	·208	M
			314·2	14·54	6·0 6·5	1	·219	
Σ 1098	26·2	59 46	286·6	26·91	9·1 9·3	2	·255	
Σ 1160	53·3	57 14	32·3	6·52	8·7 11·0	2	·202	
Σ 1172	56·8	55 1	240·8	1·67	7·0 9·0	1	·219	
Σ 1436	10 24·0	56 53	253·4	10·58	8·6 9·3	2	·356	
Σ 1495	53·7	59 27	35·0	33·94		1	·323	M
			37·6	34·62		2	·365	
Σ 1546	11 26·9	56 39	345·2	11·45	7·5 9·5	1	·361	
Σ 1553	31·1	56 41	168·0	6·16	8·0 8·2	2	·371	
Espin 182	17 21·6	63 50	19·0	5·16	9·5 11·7	3	·726	
Espin 186	18 15·7	64 2	329·2	7·73	7·8 10·7	3	·745	

Name.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
	h m	° ′	°	″			1900
Espin 127	18 46·4	+62 47	324·5	5·09	9·4 9·6	3	·715
Σ 2509	19 16·1	63 2	332·3	1·04	7·1 7·3	2	·751
Anon.	16·6	62 59	293·4	10·32	9·8 10·0	2	·751
Espin 194	20·4	64 20	219·7	5·12	8·8 9·3	3	·845
Espin 197	35·7	64 49	22·1	9·43	8·5 9·2	2	·835
Espin 199	46·4	64 26	170·2	7·26	8·3 9·6	3	·845
Espin 198	20 37·9	64 42	312·6	2·93	8·8 9·2	3	·845
Doberck	38·1	63 4	95·6	2·96	9·3 9·5	3	·705
h 3004	47·1	62 8	196·2	3·68	10·8 11·0	2	·713
h 1607	58·1	61 6	82·9	10·88	7·1 8·6	3	·741 AB
			324·7	30·61	C= 13·3	3	·741 AC
h 1654	21 26·1	61 11	30·4	5·14	9·0 9·3	5	·867
Fox	22 11·0	61 25	176·4	5·89	8·5 9·1	3	·713
Espin 148	27·4	61 6	286·0	2·82	9·3 9·5	3	·717

Notes.

A.G., $3^h\ 32^m{\cdot}8$. Given as two stars in A.G., Nos. 3134, 3135, Helsingfors-Gotha.

Kr. 27, $5^h.37^m{\cdot}3$. β measured B.D. +56°·1056 in mistake for Kr. 27.

Doberck, $20^h\ 38^m{\cdot}1$. Not in B.D. ; place 1900, $20^h\ 38^m\ 4^s{\cdot}45$; +63° 4′·3.

h 1607. C is a nearer *comes* than the one measured by β, now at 335°·5.

New Double Stars.

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
		h m	° ′	°	″			1920
1806	+56°·112	0 36·9	+57 3	236·1	5·48	8·2 12·5	2	·460
1807	+56·130	43·3	56 47	267·1	4·66	8·3 12·7	2	·865
1808	+57·253	1 13·3	57 48	325·6	5·35	9·3 13	3	·976
1809	+56·249	14·2	56 20	115·1	5·93	8·7 10·0	3	·914
1810	+55·443	49·4	56 10	300·5	5·66	9·3 13·2	3	·863
1811	+55·450	50·8	55 29	289·5	4·37	9·5 11·5	3	·965
1812	+60·556	2 35·9	60 30	84·9	1·79	9·4 10·7	3	·011, 1921
1813	+60·579	43·4	60 22	2·0	4·14	9·2 12·5	2	·863
1814	+56·729	44·6	57 7	303·9	7·22	9·5 9·7	2	·122
1815	+60·586	46·4	60 14	233·4	7·28	8·5 10·2	2	·943
1816	+60·717	3 30·1	60 13	299·2	3·35	9·3 9·3	2	·943
1817	+56·853	44·4	56 52	300·4	7·07	9·1 12·5	2	·058
1818		46·9	56 44	183·5	3·45	10·1 10·3	2	·119
1819	+60·765	47·4	60 27	128·0	7·07	8·8 12·2	3	·966

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date.
	°	h m	° ′	°	″			1920
1820		3 49·6	+56 54	242·1	4·47	10·0 11·1	2	·058
1823	+55·925	4 38·7	56 0	205·3	5·79	9·0 10·3	4	·110
1824	+56·974	41·3	56 7	81·3	6·66	9·5 12·0	2	·144
1825	W Ursæ	9 36·7	56 25	49·9	7·01	var. 13·1	3	·230
1826	+57·1339	11 47·4	57 20	232·7	7·62	8·5 12·5	2	·371
1827		16 21·6	60 31	38·4	5·18	9·6 12·0	3	·651
1828	+60·1675	22·4	60 34	242·7	3·72	9·5 10·1	3	·651
1829	+60·1711	51·0	60 38	77·3	8·45	9·4 10·2	2	·641
1830		53·7	61 18	123·0	3·26	10·3 10·7	3	·648
1831		17 18·2	62 38	266·5	4·15	9·6 12·7	3	·731
1832	+62·1555	29·7	62 39	153·9	3·64	9·5 12·0	2	·708
1833	+61·1707	52·5	61 4	261·4	7·66	7·4 12·2	2	·632
1834		18 6·2	62 29	304·3	2·77	10·0 10·3	2	·701
1835		11·0	64 16	308·5	4·06	9·6 10·7	2	·751
1836	+62·1604	12·3	62 32	152·8	3·96	9·2 11·0	2	·701
1837	+63·1422	21·2	63 55	269·3	6·60	9·2 11·0	3	·860
1838	+61·1765	39·5	61 17	141·4	6·22	9·2 12·5	2	·691
1839	+63·1449	40·5	63 5	49·3	5 25	9·5 11·5	2	·835
1840	+63·1460	44·9	63 57	221·9	9·35	8·5 9·0	2	·872
1841		50·7	62 15	104·8	2·97	9·5 12·0	5	·732
	+61·1787	53·9	61 35	165·8	11·26	9·1 9·5	2	·687
1842	+61·1791	55·4	61 36	264·1	7·17	9·5 12·7	3	·691
1843		56·9	61 51	118·2	2·75	9·5 10·8	2	·720
1844		58·5	63 39	17·8	3·32	9·6 10·5	3	·878
1845	+61·1839	19 15·7	61 49	147·0	6·64	8·3 10·0	3	·710
1846		24·2	61 38	279·6	5·64	9·6 11·0	2	·691
	+61·1863	24·6	61 34	280·4	9·08	9·2 9·4	2	·691
1847	+62·1723	28·8	62 47	223·3	3·83	9·5 10·7	3	·745
1848	+62·1732	33·1	62 36	319·7	5·66	8·2 9·9	3	·731
1849	+61·1910	46·0	61 10	152·4	4·25	8·5 11·7	3	·678
1850		54·7	63 29	214·8	6·12	9·5 12·5	3	·878
1851	+60·2055	55·0	61 6	107·7	5·56	9·5 11·7	2	·701
1852	+61·1974	20 5·7	61 25	152·2	6·48	8·5 9·1	3	·710
1853		8·1	62 2	294·3	3·75	10·9 10·9	2	·728
1854		22·3	62 2	289·4	2·43	10·6 10·7	2	·728
1855	+62·1861	47·2	62 50	27·4	4·94	9·0 11·7	2	·812
1856	+61·2186	21 40·4	61 45	52·5	5·35	8·2 12·2	4	·780

No.	B.D.	R.A. 1900. h m	Decl. ° ′	P. °	D. ″	Mags.	Nts.	Date. 1920	
1857	+61°2198	21 43·6	+61 24	208°7	2″75	9·2 9·3	3	·740	AB
				109·3	14″37	C=10·5	3	·740	AC
1858	+61·2200	45·3	62 2	208·2	4·50	9·1 13·2	4	·821	AB
				349·5	11·19	C=11·0	3	·832	AC
1859	+61·2238	22 0·4	62 4	91·7	2·79	9·3 9·5	2	·773	
1860	+61·2357	48·7	61 47	153·0	4·87	9·1 11·5	3	·973	
1861	+61·2384	58·1	61 58	290·0	4·29	8·1 12·3	3	·832	
1862	+61·2420	23 14·3	62 6	43·2	2·89	9·5 10·5	3	·947	AB
				15·0	13″97	C=13·5	2	·951	AC
1863	+60·2519	14·8	60 58	313·6	4·33	9·0 12·5	3	·797	AB
				158·2	10·03	C=10·7	3	·797	AC
1864	+61·2420	36·9	62 12	32·4	3·60	9·1 10·0	2	·913	AB

Notes.

1808. Also a 14 mag., P. 134°·0, D. 6″·0; and a 12 mag., P. 188°·7, D. 9″·2.
1815. Distant *comes* at P. 51°·9.
1820. In field at P. 250°·8, with B.D. +56°·860.
1841. In field at P. 244°·5, with B.D. +62°·1656.
1844. *Comes*, 14 mag., P. 112°·2, D. 14″·8.
1850. At P. 167°·1, D. 47″·9 from B.D. +63°·1580.

The following double stars have been found by Mr. Milburn with the 17¼-inch and measured with the 24-inch.

No.	B.D.	R.A. 1900. h m	Decl. ° ′	P. °	D. ″	Mags.	Nts.	Date. 1920	
150	+55°86	0 24·2	+55 15	302°9	4″46	9·6 9·6	2	·865	
151		56·0	58 22	237·0	5·52	9·6 10·2	2	·874	
152	+56·213	1 5·3	57 4	78·3	1·35	9·2 11·0	3	·102	
153	+57·261	13·9	57 47	153·2	4·87	9·5 13·0	4	·685	
154	+62·316	46·4	62 54	131·5	3·54	9·2 9·4	2	·920	
155		2 6·4	55 23	6·3	3·62	10·7 11·2	2	·122	
156	+55·734	53·0	55 30	181·3	3·25	9·4 13·0	3	·124	
157	+61·526	3 1·5	61 18	217·6	3·33	9·4 12·2	2	·943	
158	+60·830	4 35·0	60 56	133·6	5·60	9·5 9·6	2	·128	
159	+60·849	51·3	60 59	302·7	4·04	9·4 11·5	2	·143	
160	+60·861	5 2·3	60 49	293·0	3·72	9·5 9·6	2	·144	
161	+60·865	7·5	61 2	244·1	2·38	9·5 12·0	3	·011, 1921	
162	+60·1031	7 0·8	60 54	105·3	6·35	8·4 12·0	2	·202	
163		8 37·3	60 23	203·2	4·21	9·7 12·0	1	·183	
				204·3	4·50	10·2 11·0	1	·208	M
164	+60·1215	9 45·8	59 58	80·3	2·29	9·5 9·6	2	·201	
				81·8	2·29	9·5 9·8	1	·208	M

No.	B.D.	R.A. 1900. h m	Decl. ° ′	P. °	D. ″	Mags.	Nts.	Date. 1920	
165	+60·1234	9 57·6	+60 10	85·1	3·81	8·5 11·5	2	·253	
166	+60·1270	10 30·9	60 19	308·5	5·16	8·9 12·2	2	·253	
167	+59·1329	41·0	58 47	323·7	5·72	9·5 9·7	2	·235	
				321·1	5·49	9·5 9·8	1	·208	M
168	+56·1515	11 17·0	56 17	141·9	5·71	9·4 11·0	1	·287	
				143·1	5·95		1	·323	M
169	+57·1386	12 36·1	57 0	313·3	1·85	9·4 9·6	2	356	
170		13 3·5	55 13		3·48	11·0 11·4	2	·371	
171	+56·3806	34·5	55 50	289·5	1·87	9·5 11·0	1	·381	
172		14 4·8	55 8	60·5	2·56	11·5 12·0	1	·381	
173		19 21·0	61 6	223·1	3·79	10·0 10·1	4	·681	
174	+62·1837	20 35·3	63 3	241·6	4·62	9·2 9·4	2	·701	
175		21 37·6	62 39	89·3	2·93	9·5 12·2	2	·706	
176	+60·2298	45·6	61 10	126·5	3·72	9·0 9·2	2	·706	AB
				274·8	11·14	C= 11·0	2	·706	AC
177		46·3	62 55	44·3	2·52	11·0 11·5	3	·920	
178	+62·1988	49·1	62 27	323·8	4·15	9·3 10·3	3	·761	
				324·1	3·83		1	·764	M
179		22 11·0	62 38	150·2	2·54	9·6 10·0	2	·712	
180		39·1	62 34	189·6	6·93	9·4 10·7	2	·805	
181	+62·2182	23 6·6	62 42	190·1	2·75	9·3 9·5	2	·850	
182	+62·2297	42·6	62 49	122·7	5·24	9·5 11·2	3	·827	AB
				351·5	25·21	C= 9·8	3	·827	AC

Notes.

170. Angles 275°·6, 266°·8. Evidently a mistake of 10° in one or other angle.

Missing Stars.

	B.D.	R.A. 1855. h m s	Decl. 1855. ° ′	Mag.
(1)	+55·1010	5 32 32·5	+55 52·2	9·5
(2)	+55·1224	7 38 19·6	+55 29·8	9·4
(3)	+62·1936	21 20 55	+62 56·1	9·3

Notes.

(1) 1920 March 2, 9. Not seen. Not in H.M.S., nor on Richardson's negatives (3).
(2) 1920 March 2. No star, possibly identical with a star about 2′ south.
(3) 1920 Sept. 23. Milburn 12·0, Es. 12·5, near the place; there is a brighter star about 1^{m} p. which may be the missing star.

Nova Cygni (1920).

(*Communicated by Rev. T. E. Espin.*)

The following observations have been made by Mr. Milburn of the magnitudes of Nova Cygni (Denning).

Date 1920.	Greenwich Mean Time.	Observed Magnitude.	Comparison Stars.	Instrument.
	h m			
Aug. 27	8 30	3·2	δ Cygni	(Eye alone.)
,, 29	8 45	4·0	o^1, o^2 Cygni	,, ,,
,, 31	9 0	4·3	θ, κ Cygni	1⅜-in. binoculars
Sept. 4	9 50	4·5	ψ Cygni	,, ,,
,, 6	8 50	4·8	,,	,, ,,
,, 8	9 35	5·0	,,	,, (and eye alone).
,, 10	8 20	5·35	20 Cygni	,, binoculars.
,, 13	8 30	5·5	B.D. +52°·2623	,, ,,
,, 15	8 20	5·6+	20 Cygni; ,,	2⅛-in. ,,
,, 18	8 10	6·0	+51°·2728; ,,	,, ,,
,, 19	8 20	6·0	,, ,,	,, ,,
,, 22	9 20	6·2	+51°·2763	,, ,,
,, 23	8 20	6·5	,,	,, ,,
,, 25	8 45	6·8	,,	3¼-in. refractor.
,, 27	8 0	6·8	+53°·2303; +51°·2703	,, ,,
Oct. 7	9 0	8·5	{ +53°·2332; +53°·2335 +53°·2328	,, ,,
,, 8	8 0	8·4	+53°·2335; +53°·2332	,, ,,
,, 13	7 10	8·5+	,, ,,	,, ,,
,, ,,	7 30	8·7	,, ,,	,, ,,
,, 30	8 30	8·7+	,, ,,	17¼-in. reflector.
Nov. 5	7 30	9·2	,, +53°·2333	24-in. ,,
,, 15	7 15	9·2+	,,	,, ,,
,, 16	6 30	9·2	,, ,,	,, ,,
,, 22	6 15	9·2	,,	,, ,,
Dec. 8	7 5	9·0	,, ,,	3¼-in. refractor.
,, 10	7 20	9·1	,, ,,	,, ,,
,, 31	11 25	9·0	,, ,,	,, ,,
1921.				
Jan. 6	6 40	9·0	,, ,,	,, ,,

The Total Solar Eclipse of 1922 *September* 20. By Professor A. D. Ross, M.A., D.Sc., and Mr. R. D. Thomson, M.A., B.Sc.

The solar eclipse of 1922 September 20 offers a favourable opportunity for re-testing the Einstein Relativity Theory. In view of the partial failure at Sobral in 1919 it seems highly desirable that a fair number of stations should be occupied, and we wish to draw attention to the facilities offered on the north-west coast of Western Australia. So far it appears that only three stations are under consideration, viz. (1) Bandidu in the Maldive Islands, with a duration of totality of $4^m\ 10^s$; (2) Christmas Island, with $3^m\ 42^s$ totality; and (3) Cunnamulla in Queensland, with $3^m\ 45^s$. In our opinion it is highly advisable that a party should occupy a station near to Wollal, where about $5^m\ 18^s$ of totality is obtainable.

Speaking at a meeting of the Society in March of last year, Mr. Hinks described this part of the Western Australian coast as hopeless, and stated that motor cars were out of the question. We consider that Wollal is approachable both by sea and land, although the former method would undoubtedly be preferable for the transport of instruments.

Broome is the headquarters of the pearling industry, and vessels of various size are obtainable there for coastal trips. Luggers of 12 to 14 tons can make the 200-mile run from Broome to Wollal in from 24 hours to 5 days, depending on the weather, which is usually calm at that period of the year. Schooners of 30 to 40 tons are also obtainable, and there is a launch of about 14 tons which could make the journey within the day. Landing is effected at a creek about eight miles from Wollal, and there is from that point a fair road to Wollal telegraph station. Whale-boats can beach with the tide at a point opposite Wollal, whence the way lies for half a mile across sand dunes and then for a mile along a rough track. The creek landing is to be recommended, and there seems no reason why packages of instruments weighing two or three hundredweight should not be safely handled.

Wollal possesses an ample supply of good water, and there is a sheep station only four miles distant from which assistance in connection with the removal and erection of instruments could probably be obtained. One resident in the district possesses a motor car, and states that the road between Broome and Wollal is fair in September although rather loose in parts. Broome to Lagrange is 86 miles by road, and to Wollal is a further 110 miles.

If Wollal is to be occupied, the main stores should be obtained in Perth and taken north to Broome by the north-west coast and Singapore steamers. Minor stores could be purchased at Broome. One of the pearling fleet-owners has evinced a keen interest in the matter, and we are sure that we can obtain his assistance in making local arrangements at Broome. It is, however, imperative that early arrangements should be made for the coastal boats required at Broome and for the necessary carting at Wollal.

From the meteorological point of view Wollal gives great promise. Meteorological observations are made at 8 a.m. at the telegraph station, and the following summary will be of interest :—

Month of September.

Year:	1917.	1918.	1919.	1920.
Number of days on which observations were made	25	25	21	24
Number of days with rain	0	0	0	2
Average rainfall in inches	0	0	0	0·12
Prevailing wind during month	S'ly	S'ly	SE	SE
Average force, 0–12	1·7	1·5	3·0	1·8
Days with any cloud, 8 a.m.	8	3	9	5
Average amount of cloud, 0–10	1·4	0·6	1·3	1·2
Cloudy days, 8 a.m.	1	1	0	2

In 1920 the two days on which rain was recorded were the 7th with 0·26 inch and the 12th with 0·09 inch.

The following figures taken from the records made at Broome during several years will give a further indication of the weather conditions :—

	Month of September.	Whole Year.
Mean max. temperature	89°	89°
Mean min. temperature	65	70
Highest maximum	103	111
Lowest minimum	52	40
Average rainfall	0·06 in.	23·65 ins.

The wet months are December to March inclusive, and the average rainfall for August, September, and October does not exceed 0·06 inch in any month.

It therefore occurs to us that Wollal has many advantages in respect of weather conditions and of long duration of totality, and it is our opinion that the difficulties of transportation of instruments are not unreasonably great. We shall be glad to obtain any further information desired by any party contemplating the occupation of this district.

University of Western Australia,
Perth, W.A. :
1920 *December* 14.